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# PROCEEDINGS OF THE WORKSHOP ON COOL BUILDING MATERIALS

## National Institute of Standards and Technology
## Gaithersburg
## February 28, 1994


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## Preface

The Option 9, Cool Communities, of the Clinton-Gore Climate Change Action Plan (CCAP) calls for mobilizing community and corporate resources to strategically plant trees and lighten the surfaces of buildings and roads in order to reduce cooling energy use of the buildings. It is estimated that Cool Communities Project will potentially save over 100 billion kilowatt-hour of energy per year corresponding to 27 million tons of carbon per year by the year 2015. (See attached copy of CCAP: Option 9)

To pursue the CCAP's objectives, Lawrence Berkeley Laboratory (LBL) on behalf of the Department of Energy and the Environmental Protection Agency, in cooperation with the Building and Fire Research Laboratory of the National Institute of Standards and Technology (NIST), organized a one-day meeting 1) to explore the need for developing a national plan to assess the technical feasibility and commercial potential of high-albedo ("cool") building materials, and if appropriate, 2) to outline a course of action for developing the plan. The meeting took place on February 28, 1994, in Gaithersburg, Maryland.

The proceedings of the conference, Cool Building Materials, includes the minutes of the conference and copies of presentation materials distributed by the conference participants. We hope that the materials assembled in this proceedings provide an introductory background needed by the various interested parties and encourages a wider participation in the next conference/workshop.

Conference Co-chairs
Hashem Akbari (LBL)
Geoffrey Frohnsdorff (NIST)

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*Attendance List*

# COOL BUILDING MATERIALS WORKSHOP

NIST Building 224 Room B245
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| Name | Company | Phone |
|---|---|---|
| Hon. Renz Jennings | Arizona Public Service Commission | 602-542-3935 |
| John Sullivan | American Portland Cement Alliance | 708-966-6200 |
| Russell Snyder | Asphalt Roofing Manufacturers Association | 301-231-9050 |
| Danny S. Parker | Florida Solar Energy Center | 407-783-0300-162 |
| John Hoffman | Environmental Protection Agency | 202-233-9190 |
| Tracey Narel | Environmental Protection Agency | 202-233-9145 |
| Margret Rostker | Electric Power Research Institute | 202-293-7512 |
| Doug Reindl | Electric Power Research Institute: Commercial Building Center | 608-265-3010 |
| Mike Italiano | Green Buildings Council | 202-778-0760 |
| Hashem Akbari | Lawrence Berkeley Laboratory | 510-486-4287 |
| Art Rosenfeld | Lawrence Berkeley Laboratory | 510-486-4834 |
| Paul Berdahl | Lawrence Berkeley Laboratory | 510-486-5278 |
| Tom R. Brumagin | National Asphalt Pavement Association | 301-731-4748 |
| Gary R. Fore | National Asphalt Pavement Association | 301-731-4748 |
| Geoffrey Frohnsdorff | National Institute of Standards and Technology | 301-975-6706 |
| Jim Hill | National Institute of Standards and Technology | 301-975-6706 |
| Robert A. Garbini | National Ready -Mixed Concrete Association | 301-578-1400 |
| Martin Petchul | National Research Center: National Association of Home Builders | 301-249-4000 |
| William Good | National Roofing Contractors Association | 708-299-9070 |
| David L. Yarbrough | Oak Ridge National Laboratory | 615-372-3494 |
| Joe Hobson | Roof Coatings Manufacturers Association | 301-230-2501 |
| Joseph Malpezzi | Single Ply Roofing Institute | 617-237-7879 |
| Peter Fox-Penner | US Department of Energy | 202-586-6593 |
| William Freeborne | US Department of Housing and Urban Development | 202-708-4370 |
| Melvin Pomerantz | Unaffiliated | 914-762-0459 |

*Agenda*

## COOL BUILDING MATERIALS WORKSHOP

NIST Building 224 Room B245
Gaithersburg, Maryland

February 28 1994

Chair: **Hashem Akbari** (Lawrence Berkeley Laboratory)

1. 1. INTRODUCTORY SESSION (9:30 to 11:00)
   - **Peter Fox-Penner** (DOE):
     Clinton Climate Action Plan #9 Cool Communities
   - **Art Rosenfeld** (LBL):
     The potential for energy savings from cool materials.
   - **Paul Berdahl** (LBL):
     Technical issues for the development of cool materials
   - **Geoff Frohnsdorff** (NIST):
     The National Program for High-Performance Construction Materials and Systems

2. INTRODUCTION AND SHORT PRESENTATIONS FROM PARTICIPANTS (11:15-12:30)

Chair: **Geoffrey Frohnsdorff** (National Institute of Standards and Technology)

3. DISCUSSION OF ISSUES (1:30-2:30)
   - Is there a need for a national program on cool building materials? If so, should the program be planned jointly by industry and government?
   - What should be the objective of the program? How should the program be structured?
   - Who should be involved in the planning?
   - Should there be a technical workshop or symposium to draw attention to the existing knowledge and inspire future materials research?

6. DEVELOPMENT OF AN ACTION PLAN AND TIME TABLE (2:30-3:30)

7. ADJOURNMENT (3:30)

**REPORT FROM THE COOL BUILDING MATERIALS WORKSHOP†**

**Cosponsored by Lawrence Berkeley Laboratory and the Building and Fire Research Laboratory of the National Institute of Standards and Technology**

**Held at The National Institute of Standards and Technology, Gaithersburg, MD, on February 28, 1994**


**SUMMARY**

A workshop to discuss the need for a national program on "cool building materials" was held on February 28, 1994. The participants included representatives of building materials trade associations and others interested in conservation of energy and the environment. After being briefed on "cool building materials" (i.e. materials that, as a result of their high reflectivity in the visible and near infrared, remain relatively cool when exposed to solar radiation), on the Administration's Cool Communities Program, and on the Civil Engineering Research Foundation's High-Performance, Construction Materials and Systems Program, the participants' were asked to address questions such as, Is there a need for a national program on cool building materials? And if so, what should be the objective and how should it be planned? At the end of the workshop, it was agreed that there was a need for a national program on cool building materials and that industry and designers should be involved in the planning. The objectives should be, essentially, to ensure that information on cool building materials is available to designers, maintenance personnel, regulatory authorities, and others who need it to make decisions on cool buildings. It was also agreed that an open meeting and workshop should be held before the end of July, 1994 to brief a larger group from industry on the need and to seek their help in establishing a national program. NIST was asked to chair an industry/government steering committee to organize the meeting and workshop and draft an outline of a national program.


## 1. INTRODUCTION

A workshop to discuss the need for a national program on "cool building materials" was held at the National Institute of Standards and Technology (NIST) from 9:30 a.m. to 3:30 p.m. on February 28, 1994. The workshop was organized by the Lawrence Berkeley Laboratory (LBL) and NIST's Building and Fire Research Laboratory. A list of participants is included (page 2). Hashem Akbari of LBL and Geoff Frohnsdorff of NIST were cochairs.


† This workshop was supported by the US Environmental Protection Agency and the Department of Energy.

## 2. PURPOSE OF THE WORKSHOP

The purpose of the workshop was to provide the participants with important background information on cool building materials (i.e. materials that, as a result of their high reflectivity in the visible and near infrared, remain relatively cool when exposed to solar radiation) and the Administration's Cool Communities Program, and then seek the participants' help in answering the following questions:

- Is there a need for a national program on cool building materials? If so:
- Should the program be planned by a joint government and industry group?
- What should be the objectives of the program?
- How should the program be structured?
- Should there be a conference or symposium on cool building materials?

Finally, if the answers to the questions warranted it, an action plan should be drawn up.

## 3. BACKGROUND INFORMATION

The morning session was chaired by Hashem Akbari of LBL. It provided background information relevant to the issues to be addressed. The speakers were Art Rosenfeld of LBL, Paul Berdahl of LBL, Peter Fox-Penner of DoE, and Geoff Frohnsdorff of NIST.

*a) The Potential for Energy Savings from Cool Materials*

Rosenfeld reviewed the results of LBL research on the effects of the spectral reflectivity of surfaces exposed to solar radiation in hot climates, particularly the roofs of buildings and pavements, on air conditioning use in buildings and on ambient air temperatures in communities. He pointed out that lower ambient air temperatures in communities could lead to reduced energy use and less smog. This was illustrated by the results of model calculations for the Los Angeles region. Many of the details of Rosenfeld's talk were given in copies of a paper he distributed -- Rosenfeld, Akbari, Bretz, Fishman, Kurn, Sailor and Taha, "Mitigation of Urban Heat Islands: Materials, Utility Programs, Updates". Following Rosenfeld's presentation, Danny Parker of the Florida Solar Energy Center mentioned their studies which are summarized in Attachment 2, Measured Cooling Energy Savings for Reflective Roof Coatings in Florida. Attachment 3 is a copy of a letter indicating support for the concept of highly reflective roofs that Rosenfeld had received from Bruce Vincent of the Sacramento Metropolitan Utility District who, unfortunately, was unable to attend the workshop.

The major questions asked by the audience included:

- the impact of surface aging on albedo,
- the uncertainties in smog calculations,
- how (or if) cool building materials are implemented by South Coast Air Quality Management District (SCAQMD),
- the impact of cool building materials on winter heating load,
- the payback time of cool materials, and
- the need for a rating system to measure performance of cool building materials.

The need for a national database on the availability and performance of existing cool building materials was also discussed.

*b) Technical Issues for the Development of Cool Materials*

Berdahl pointed out that about half of the energy in the solar spectrum is in the visible range and half in the near infrared. He then presented visible and near-infrared reflectance spectra for several roofing materials and coatings to illustrate how large the differences can be. He mentioned that most of the emission of heat from the surfaces of the building materials he investigated occurs in the far infrared where differences in the emissivities are not great. As a result, proper choice of materials can result in significantly lower temperatures of surfaces exposed to the sun. A summary of this presentation is included as Attachment 4.

*c) The President's Climate Change Action Plan, Option 9: Cool Communities*

Fox-Penner spoke of the President's Climate Change Action Plan (CCAP). DoE has a strong program in the development of codes and standards that can complement an ambitious voluntary market-based deployment mechanism for energy conservation technology. DoE spends about $100M/y on materials research, including research on building materials in which it has renewed interest and a desire to bring the research to the point of commercialization. They believe that there are some new paving and roofing materials that will be useful in Option 9 of the CCAP, Cool Communities. A draft of the DoE Cool Communities proposal will be available in March. Copies will be sent to all participants in the workshop. Funding for the program will be $3M in FY1995 and support is expected to continue for several years. There is a need for consortia of manufacturers, scientists, engineers, and regulators to discuss whether some new materials are close to the market place and, if so, how to get them there.

*d) CERF's Program on High-Performance Construction Materials and Systems*

Frohnsdorff mentioned the Civil Engineering Research Foundation (CERF, an arm of the American Society of Civil Engineers) and the national program it had announced in a call-to-action on April 29, 1993, "High-Performance Construction Materials and Systems: An Essential Program for America and Its Infrastructure." (CONMAT) Following publication of plans for research, development, and technology transfer on high-performance concrete and steel, the CERF Program brought together other parts of the building materials industry to draft plans for more classes of construction materials -- aluminum, asphalt, coatings, composites, masonry, roofing materials, smart materials, and timber. Frohnsdorff suggested that, since the CERF program includes asphalt, coatings, concrete, and roofing materials, it would be logical to extend its scope to include cool building materials. A summary of Frohnsdorff's presentation and the newsletter of CERF's construction materials program is included as Attachment 5.

*e) Comments from a Utility Commissioner*

The Honorable Rez D. Jennings, Commissioner of the Arizona Corporation Commission and Chairman of the Renewable Energy subcommittee of the Conservation Committee of the National Association of Regulatory Utility Commisioners (NARUC) spoke enthusiastically about the cool communities concept and its relevance to Arizona. He would like to see a national cool building materials program established.

## 4. THE NEED FOR A NATIONAL PROGRAM ON COOL BUILDING MATERIALS

The afternoon session, chaired by Geoff Frohnsdorff of NIST, was devoted to issues raised in the morning session. Following a general discussion, it was agreed that there was a need for a national program on cool building materials. The program will be coordinated with the larger program on cool communities.

## 5. PROPOSED OBJECTIVES FOR A NATIONAL PROGRAM

While the exact wording may need to be modified, it was agreed that the objectives of the program should be, essentially:

a) To ensure that information on cool building materials is available to designers, maintenance personnel, regulatory authorities, and others who need it to make decisions on cool buildings.

b) To develop a mechanism for creating a demand for cool building materials.

Among comments made during the formulation of the objectives were that factors to be considered should include:

- The need for basic and other research and the delivery of existing technology
- The need for a voluntary, uniform, cool material rating system, and a data base
- How cool building materials fit into the total system, including the effects of vegetation and shading, building orientation, and road surfaces
- The need for coordination with the Green Buildings program and the Executive Order on Recycling
- The relative benefits from the use of cool materials (e.g., fire safety, worker safety, and benefits to society as a whole)
- Who pays?

## 6. SUGGESTED PARTICIPANTS IN THE PLANNING OF A NATIONAL PROGRAM

It was agreed that planning of the national program should involve organizations from both the private and public sectors and representatives of the industrial, scientific and design communities. Specific private sector organizations mentioned were:

* American Institute of Architects (AIA)
* American Portland Cement Alliance (APCA)
American Public Works Association (APWA)
American Society of Civil Engineers (ASCE)
Asphalt Roofing Manufacturers Association (ARMA)
Building Owners and Managers Association (BOMA)
Civil Engineering Research Foundation (CERF)
* Green Buildings Council
* National Asphalt Paving Association (NAPA)
* National Roofing Contractors Association (NRCA)
Roof Coating Manufacturers

and general categories were:

Landscape architects
Metropolitan planning organizations
Utilities

On the public side, organizations named were:

American Association of State Highway and Transportation Officials (AASHTO)
* Environmental Protection Agency (EPA)

Federal Highway Administration (FHWA)
Florida Solar Energy Center (FSEC)
* Lawrence Berkeley Laboratory (LBL)
* National Institute for Standards and Technology (NIST)
Oak Ridge National Laboratory (ORNL)
Office of Science and Technology Policy (OSTP)

* These organizations are to be invited to serve on a steering committee for the next stage of planning (see the Action Plan in Section 8). NIST was asked to lead the steering committee.

## 7. COOL BUILDING MATERIALS CONFERENCE AND WORKSHOP

Discussion of a suggestion that a technical conference on cool building materials be organized resulted in agreement that the immediate need was for a one-day open briefing on the subject for building material manufacturers and other interested parties. The purpose would be to let as large as possible a group of those who should be involved know about the opportunities. The briefing should be followed on the next day by a one-day workshop at which the participants in the briefing could express their views on how the program should be developed and how they could and should contribute to the program. Three essential topics will be adressed at the workshop, labels, implementation programs, and a materials database.

## 8. ACTION PLAN

At the end of the workshop, several actions were agreed on. The actions and the target dates for completion were:

| | |
|---|---|
| Form a Steering Committee | March 15 |
| Review and respond to the DoE plan | April 15 |
| Draft a plan for a national program | June 30 |
| Hold a conference (briefing) and workshop to discuss future actions | June 30 |

## ATTACHMENT 1

A.H.Rosenfeld et al.
Mitigation of Urban Heat Islands: Materials, Utility Programs, Updates

This paper is an expansion of Art Rosenfeld's presentation at the workshop. It provides a background and summary of the current research on summer urban heat islands, and the potential for cool building materials as a mitigation strategy.

# Mitigation of Urban Heat Islands: Materials, Utility Programs, Updates[†]

Arthur H. Rosenfeld
Hashem Akbari
Sarah Bretz
Beth L. Fishman
Dan M. Kurn
David Sailor
Haider Taha

Heat Island Project [‡]
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Draft: April 4, 1994

## Abstract

Elevated temperatures in urban "heat islands" increase cooling energy use and accelerate the formation of urban smog. Urban shade trees and light-colored surfaces can offset or reverse the heat island and conserve energy. We present recent measurements of the air-conditioning savings for houses in Sacramento and Florida, and air temperature measurements at White Sands National Monument, New Mexico. We also discuss the results of meteorological and smog simulations for the Los Angeles Basin.

The albedo of a city may be increased gradually if high-albedo surfaces are chosen to replace darker materials during routine maintenance of roofs and roads. Such high-albedo surfaces may last longer than their conventional dark counterparts. Utility-sponsored incentive programs, product labeling, and standards could promote the use of high-albedo materials for buildings and roads.

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† An earlier version of Sections 1-5 of this paper was presented to the NIGEC (National Institute for Global Environmental Change) "Supercities Conference," San Francisco, October 28, 1992, and will be published in Urban Atmosphere/Atmospheric Environment (1993).

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## Contents



## 1. Introduction

Modern urban areas usually have dark surfaces and less vegetation than their surroundings. These differences affect the climate, energy use, and habitability of cities. At the building scale, exposed dark exterior surfaces become hot and thus raise the summertime cooling demands of buildings. Collectively, the dark surfaces and reduced vegetation warm the summer air over urban areas, leading to the creation of the summer urban "heat island." On a clear summer afternoon, the air temperature in a typical city is about 2.5°C (5°F) hotter than the surrounding rural area. Akbari et al. [1992] have found that peak urban electric demand in six American cities (Los Angeles, CA; Washington, DC; Phoenix, AZ; Tucson, AZ; and Colorado Springs, CO) rises by 2 - 4% for each 1°C rise in daily maximum temperature above a threshold of 15 to 20 °F. Thus, the additional air-conditioning use caused by this urban air temperature increase is responsible for 5-10% of urban peak electric demand, at a direct cost of several billion dollars annually.

The Heat Island Project at the Lawrence Berkeley Laboratory has examined both the building- and city-scale effects of the urban surface on energy use and climate. We find that increasing the albedo[1] of urban surfaces and planting trees in urban areas can limit or reverse the urban heat island effectively and inexpensively. Both of these improvements can be implemented by 1) rating and labeling roofing materials by their minimum midday temperature; 2) adopting relatively mild standards (for example, that new roofs run cooler than halfway between the surface tempertures of typical white and black surfaces) and 3) offering rebates on new roofs (or re-roofs) for beating the standards.

## 2. Building-Scale Effects

The direct effect of lowering the albedo of a surface and removing the surrounding vegetation is to increase its solar heat gain and thus its surface temperature. If the surface is the roof or wall of a building, the increased heat gain directly increases the cooling energy use and peak cooling demand of the building.

[1] Albedo is defined as hemispherical reflectivity integrated over the solar spectrum. Low-albedo surfaces absorb a larger portion of the incident insolation and become hotter than high-albedo surfaces. Most high-albedo surfaces are light-colored, although selective surfaces which reflect a large portion of the infrared solar radiation but absorb some visible light may be colored, yet have relatively high albedos.

**Figure 1** shows the midday temperatures of various horizontal surfaces exposed to sunlight on a clear and windless summer day in Austin, Texas. For highly absorptive (low-albedo) surfaces, the difference between the surface and ambient air temperature, $\Delta T_{S\text{-}a}$, may be as high as 55°C (100°F), while for less absorptive (high-albedo) surfaces, such as white paint, $\Delta T_{S\text{-}a}$ is about 10°C. For this reason, shade trees (which reduce the insolation on a surface) and cool surfaces (which absorb little of the incident insolation) are effective means of direct cooling and reducing energy use. Through direct shading and evapotranspiration, trees reduce summer cooling energy use in buildings at about 1% of the capital cost of avoided power plants plus air-conditioning equipment [Akbari et al., 1990]. Cool surfaces are more effective than trees, and cost little if color changes are incorporated into routine maintenance schedules. Also, the results from light-colored surfaces are immediate, while it may be ten or more years before a tree is large enough to produce significant energy savings. Akbari et al. [1989] discuss the relative benefit/cost of white surfaces vs. trees.

## 2a. Measured Energy Savings from Direct Cooling in Sacramento

In summers of 1991 and 1992, we conducted experiments to measure the impact of white roofs and shade trees on six buildings in Sacramento [Akbari et al., 1993]. We collected data on air-conditioning electricity use, indoor and outdoor dry-bulb temperatures and humidities, surface temperatures of roof and ceiling, inside and outside wall temperatures, solar intensities, and wind speeds and directions.

To measure the impact of **shade trees**, we monitored two houses in a "flip-flop" experiment, divided into three periods. In the first period, we monitored the cooling energy use of both houses in order to establish a base case relationship (see **Figure 2**). In the second monitoring period, eight large and eight small shade trees were placed at one of the sites (Site D) for a period of four weeks and then, for the third period, the trees were moved to the other site (Site C). The cooling energy use of the site without trees indicates what the cooling energy use of the shaded site would have been were the trees not there. Figure 2 shows savings of 35% of the median air-conditioning load of the unshaded houses.

To measure the impact of **white roofs and walls**, we monitored the cooling energy use of a house and two school bungalows. We monitored the house in its original condition to obtain pre-modification data. The albedo of the house roof at that time was 0.18. The next year, post-modification data were collected after the albedo of the roof had been increased to 0.73. **Figure 3** shows the daily cooling-energy use of the house plotted against daily average dry-bulb outdoor temperature. The daily average outdoor temperature that causes the air-conditioning unit to turn on has shifted upward by 2°C. The lines on Figure 3 are regression fits up to 25°C. Past this point, it is difficult to compare pre- and post-modification data because there are no pre-modification data with comparable environmental variables. The seasonal cooling energy savings at this site are estimated to be 40% (330 kWh/yr.).

At a school site, one of the two school bungalows was used as a control site and remained white roofed and walled all summer. The second building was monitored simultaneously in three different conditions: (1) unpainted metal roof and yellow walls, (2) brown roof and brown walls, and (3) white roof and white walls. Comparing the cooling energy use of the control building with the test bungalow in both conditions 1 and 2 revealed energy savings of 40 - 50%, and peak power reductions of 0.6 kW, or ~35%.

To estimate the energy savings which would result from a combination of albedo and tree shading modifications, we performed a series of simulations of the energy use of prototypical buildings. We used the DOE-2.1E building energy simulation program and building prototypes developed at the Lawrence Berkeley Laboratory. We simulated the effect of increasing the albedo of the roof and walls of the building in two increments, and increasing the number of shade trees at the site by one, two, four, or eight trees. **Figure 4** shows the percentage of annual base case air-conditioning use required by a residential building prototype under different combinations of albedo and tree shading modifications. This prototype represented common building practices by having R-30 insulation in the roof, R-11 insulation in the external walls, and double-glazed windows. A combination of large albedo increase and extensive tree shading reduces annual air-conditioning use to 43% of base case values. The actual savings may be even higher. Another series of simulations were performed using the building descriptions of the buildings monitored in the experiment. A comparison of the simulation results and measured savings indicated that the building simulations underestimate the energy savings by as much as twofold.

### Direct Cooling in Florida

In 1991 – 1993, Parker et al. [1993, 1994] of the Florida Solar Energy Center (FSEC) measured the impact of reflective roof coatings on air conditioning energy use in six homes in central Florida. The roof insulations of the six homes, as summarized in **Table 1**, range from fully insulated (R-25 at Site 1), to uninsulated (Site 6) (from Parker et al. 1994). The roof albedos of these houses were raised to 0.61 - 0.73 from initial values of 0.08-0.31. Cooling-energy savings at the six homes averaged 9.2 kWh/day, or 23 % of pre-modification use. The measured air-conditioning energy savings were approximately inversely related to roof insulation—from 11% savings in the R-25 house to 43% savings in the uninsulated house. The reported utility-coincident peak demand reductions between 5 and 6 PM are 0.44 - 0.99 kW, averaging as 0.69 kW or 27% of pre-retrofit peak demand. **Figure 5** shows the roof air space temperature and the air conditioning energy use before and after the application of reflective coating on the uninsulated house (Site 6) on July 31, 1992. This study concluded that reflective coatings are particularly appropriate for existing Florida homes in which the roof structure makes insulation retrofitting difficult.

**Table 1: Roof characteristics, pre- and post-modification albedos, air-conditioning energy savings, and utility-coincident peak demand reductions for six homes in central Florida. All percentages are of pre-modification conditions (Parker et al., 1994).**

| Site | Roof Type | Insulation | albedo before | albedo after | Energy Savings (kWh/day) | 5-6 PM Load Reductions (kW) |
|---|---|---|---|---|---|---|
| 1 | asphalt shingles, concrete block | R-25 (ceiling) | 0.22 | 0.73 | 4.0 (11%) | not measured |
| 2 | gravel roof | R-11 (attic) | 0.31 | 0.62 | 8.0 (15%) | 0.44 (16%) |
| 3 | asphalt shingles and flat gravel, | R-11 (attic) | 0.21 | 0.73 | 10.3 (25%) | 0.66 (28%) |
| 4 | tile roof | R-10 (attic) | 0.20 | 0.64 | 11.6 (20%) | 0.99 (23%) |
| 5 | asphalt shingles† | ~R-3 (ceiling) | 0.08 | 0.61 | 5.6 (25%) | 0.50 (30%) |
| 6 | tar paper, flat roof | none | 0.20 | 0.73 | 15.4 (43%) | 0.86 (38%) |
| Average | | | 0.20 | 0.68 | 9.2 (23%) | 0.69 (27%) |

† Only site without attic duct system.

## 3. City-Scale Effects

When a region of dry, low-albedo, unshaded surfaces (i.e. a city) is exposed to sunlight, the surfaces become very hot, and in turn warm the air throughout the region. This climatic effect is quite substantial. Daytime summer urban heat islands with temperatures 2-3°C higher than surrounding areas are found throughout the U.S. In Los Angeles, peak temperatures are ~3°C higher than their 1940 levels, and are increasing faster than 0.5 °C per decade (**Figure 6**). These high air temperatures strongly affect the energy use and air quality of a city. **Figure 7** shows the relationship between peak power for Southern California Edison (which supplies three-fourths of the electricity for the Los Angeles Basin), and the maximum daily temperature. For every rise of 1°C in air temperature above 65 °F (18 °C), peak cooling demand in Los Angeles increases by 3.0%. In Atlanta, the increase is 6.0% per degree [Ref__]. The summer Los Angeles heat island thus accounts for 1.4 GW (gigawatt) of peak power [Akbari et al. 1990]. Nationally, heat islands raise air conditioning demand by about 10 GW, costing ratepayers several million dollars per hour, and a billion dollars annually.[2]

### 3a. Regional Cooling by High-Albedo Surface at White Sands National Monument, New Mexico.

To observe the large-scale effect of albedo on air temperature, we have begun to study the climate of White Sands National Monument, New Mexico. The surface of the Monument is composed of white gypsum sand, which has a high albedo (near the middle of the Monument the average albedo is 0.6) and little vegetation cover, since the soil is alkaline. The surrounding desert, at the same altitude of about 4000 ft., is sparsely vegetated with dry, low desert scrub and is characterized by an albedo of 0.26. Hence, the albedo difference between the Monument and the desert is about 0.35, comparable with the conceivable improvement in the albedo of large portions of a city like Los Angeles (but not dense high-rise downtown areas, like parts of Manhattan).

**Figure 8** shows the average difference in average hourly dry-bulb air temperature measurements made at weather stations installed over the light Monument and dark surroundings during August 1992 and June 1993. In the morning hours, the air over the Monument is 3°C cooler than the air over the dark surface. The air remains cooler throughout the daytime hours, although later in the day the amount of cooling is reduced because of increased upwelling.

### 3b. Meteorological Modeling of Albedo Modification in Los Angeles

To simulate the results of changing the albedo of an urban area, we used the Colorado State University Mesoscale Model (CSUMM)[3], modified to study the impacts of proposed surface changes in the Los Angeles Basin (Sailor and Kessler 1993). A rectangular region extending 325 km east-west and 200 km north-south was divided into 2600 surface grid cells, each 5 km by 5 km. A land-use database was used to characterize the surface of each cell.

We identified 394 grid cells (about 10,000 $km^2$), in which over 20% of the land is covered by artificial surfaces, as "developed areas" suitable for modification, shown in **Figure 9a**. An albedo modification was carried out on the urban surfaces in each cell as described in **Table 2**. This modification raised the average albedo of the developed areas by 0.16, from 0.16 to 0.32.

**Figure 9b** shows the temperature changes resulting from the albedo modification with respect to the base case simulations for 9 AM. As shown in **Figure 9c** for noon, the largest cooling, around 2°C, occurs over downtown Los Angeles (an area with air-conditioning use). The peak impact occurs in the early afternoon. **Figure 9d** illustrates that this potential cooling exceeds 3°C at 3 PM. We have conducted similar simulations under various initial conditions, all of which

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[2]The avoided cost of electricity is discussed in § 4, just above Equation (3).

[3] The CSUMM is a hydrostatic, incompressible, primitive-equation mesoscale meteorological model designed for simulation of airflows generated by differential surface heating and terrain irregularities. This model was originally developed by Pielke at Colorado State University. Over the past two decades, the CSUMM has been validated and applied in numerous situations. For a detailed description of the model, see Mahrer and Pielke (1977, 1978) and Arritt (1985).

indicate peak summertime temperature reductions between 2 and 4°C. According to Figure 7, a cooling of this magnitude would reduce peak power consumption in Los Angeles by 0.6 to 1.2 GW (worth between $100,000/hour and $200,000/hour, based on a cost of 16.5¢/kWh derived in Section 4).

**Table 2: Albedo modifications for sloped roofs, flat roofs, and roads assumed in meteorological modeling of albedo modification in the Los Angeles Basin. Albedo of urban surfaces rises from 0.30 to 0.50. Average albedo change of developed cells is 0.16 (Sailor 1993).**

| Surface Type | Fraction of Land Cover | Albedo Before | Albedo After | Albedo Change |
|---|---|---|---|---|
| Sloped roofs | 0.15 | 0.25 | 0.6 (light beige) | 0.35 |
| Flat roofs | 0.15 | 0.25 | 0.75 (white) | 0.5 |
| Roads | 0.30 | 0.15 (asphalt) | 0.4 (concrete) | 0.25 |

The albedo increase of 0.16 which we considered in the simulations does not imply a glaringly white city. This increase can be accomplished by brightening sloped roofs, which are visible to passers-by, to the brightness of light beige; brightening flat roofs, typically those of apartment and commercial, to bright white; and raising the albedo of asphalt roads to that of weathered concrete (Table 2). If whiter cities become popular, as they are traditionally in tropical regions and, recently, in Arizona, we could raise the average albedo by as much as 0.3. The average surface temperature resulting from this increase in albedo is 60 °C (140 °F), as indicated in Figure 1 (labeled as "Hypothetical White City"). Such a city would be even cooler than the city described by our simulations.

Urban air temperatures can also be reduced substantially through a combination of albedo modification and tree planting. Although trees are dark, they cool the surrounding air by two processes. First, they help cool their surroundings by shading even darker surfaces. Second, the evapotranspiration of trees, drawing ground-water to the plant surface where the water evaporates, reduces sensible heating of the hot surrounding air and creates a cool "oasis." This regional oasis effect is evident in the weather records of cities built in arid environments. For example, in Los Angeles, the maximum air temperatures decreased during its early development, as dry arid regions were replaced with irrigated orchards and farmland (see Figure 6). We believe that the cooling resulting from a combined albedo/tree program could mitigate or perhaps *reverse* the summertime heat island effect.

The results of the CSUMM model suggest the following relationship for the depression of summer peak temperature by increasing the albedo of a city:

$$\frac{\Delta T}{\Delta a} = \frac{(-3\pm1)\ ^{\circ}\mathrm{C}}{0.16} = -19\pm6\ (^{\circ}\mathrm{C})\ \text{[Los Angeles, model, max } \Delta T] \qquad (1)$$

where $\Delta T$ is the change in air temperature and $\Delta a$ is the change in albedo. The measured temperature depression at White Sands yields a much smaller ratio:

$$\frac{\Delta T}{\Delta a} = \frac{(-2\pm1)\ ^{\circ}\mathrm{C}}{0.35} = -6\pm3\ (^{\circ}\mathrm{C})\ \text{[White Sands, measured, avg } \Delta T] \qquad (2)$$

The difference between the simulation and measured results highlights the fact that the difference in climate between the city and its surroundings results not only from the change in albedo, but from other differences in the surface characteristics. In addition to being dark, urban surfaces are also very rough (rectangular buildings, trees, and urban canyons), relatively impermeable to water, and sparsely vegetated. The urban surface also has a high heat storage capacity, and urban canyons reduce the ability of the surface to dissipate this stored heat (all of these characteristics are represented in the CSUMM model). Thus the measured results from White Sands cannot be extrapolated directly to urban areas.

To measure the actual climate effects of urban albedo modification and tree planting, we are seeking innovative developers to build half of their subdivisions conventionally, and half with shade trees and cool roofs and roads. We would then monitor these developments to observe the variation in air temperature and savings in air conditioning resulting from neighborhood-scale modifications.[4]

## 3c. The Effect of Heat Islands on Air Quality

Heat islands have several effects on urban air quality. The power needed to compensate for islands requires significant additional generating capacity, which contributes to urban air pollution.[5] Further, elevated temperatures associated with heat islands accelerate the formation of smog. Figure 7 shows that the probability of smog increases by 6% per °C in maximum daily temperature, above a threshold of 22 °C (72 °F). However, the urban heat island also raises the mixing height under which air is constantly mixed due to free convection and turbulence off the city surface. This increase in mixing height reduces smog by dispersing air pollutants in a larger volume of air.

We are actively studying the effect of heat island mitigation on urban air pollution. We insert the CSUMM results (such as those discussed above) into the Urban Airshed Model to simulate the production of smog in the Los Angeles Basin. Preliminary results for a moderate change in albedo (half of that described in Table 2) indicate 20% reductions in peak smog in some parts of the city, but 10% increases in others.

## 4. Costs and Potential Savings

The costs of increasing the albedo and vegetation cover of a city are quite low. Albedo modifications may be very inexpensive if performed during routine maintenance. Roofs are typically refinished every 10 - 20 years, and cooler roofing material is either available or can be developed with little increase in cost. Cool pavement could be installed at the time of resurfacing. "White topping" (resurfacing an asphalt pavement with concrete) produces a light-colored pavement with low maintenance costs and a long service life. Another light-colored pavement, popular in Great Britain, is produced by rolling white chippings into the top surface of the pavement [Ref__]. Such light-colored surfaces show less damage caused by daily thermal expansion and contraction than dark ones and thus may have longer service lives. We are currently working with industry and other researchers to further develop durable high-albedo materials.

On the other hand, the potential reductions in energy consumption and costs, and carbon emissions are quite high. The national air-conditioning energy use in 1990 was around 420 BkWh (Competitek, 1992). We computed the projected national air-conditioning energy use for 1995

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4 Danny Parker of FSEC informs us that this is being done in Homestead, FL, where homes destroyed by Hurricane Andrew in 1992 are being rebuilt with shade trees and cool roofs and roads by Habitat for Humanity. FSEC will compare the energy use of ten light-roofed homes to ten otherwise identical homes over the next 2-3 years.

5 In the Los Angeles Basin, for example, most base load power is generated outside the Basin and does not contribute to urban air pollution. However, most peak power is generated within the Basin by inefficient gas-powered turbines.

through 2015, assuming an annual rate of increase of 1% (Koomey, 1994). As shown in line 1a of **Table 3**, consumption rises to 540 BkWh by 2015.

Next we calculate the cost of a kWh of air-conditioning. According to the 1995 General Rate Case submitted by the Southern California Edison Company, marginal energy values are approximately 4¢/kWh for on-peak production (around 600 hours per summer), and 3¢/kWh for mid-peak production. To this we add the marginal capacity values of 10¢/kWh for on-peak generation (i.e. capital costs of new equipment), and 1¢/kWh for mid-peak production. Thus, the total cost of peak power comes to 14 ¢/kWh, and that of non-peak power comes to 4 ¢/kWh, as shown in Table 3. Assuming that a typical HVAC unit operates for 600 hours during peak hours and for 1400 hours during off-peak hours yearly, we find the average cost of air-conditioning electricity is

$$\text{Utility cost} = \frac{600 \text{ Peak hours} * \frac{14¢}{\text{kWh}} + 1400 \text{ Off-peak hours} * \frac{4¢}{\text{kWh}}}{2000 \text{ Total hours}} = \frac{7¢}{\text{kWh}} \quad (3)$$

To this utility cost, we add the HVAC equipment costs. The cost of one ton of HVAC equipment, which draws 1 kW, is about $500 (Means Building Construction Cost Data, 1991 ). Assuming a 10% capital recovery rate (CRR) for a 30-year service life, the annual cost of this equipment is ~$50. Averaging the typical year operation time of residential HVAC units (1300 hours) and commercial ones (2500 hours), we estimate that the average HVAC unit operates for 2000 hours yearly. Thus, we calculate the HVAC equipment cost of air-conditioning as

$$\text{HVAC unit cost} = \frac{(\text{Cost of HVAC unit}) * \text{CRR}}{(\text{Hours of operation}) * (\text{Power of unit})} = \frac{\$500 * 10\%}{2000 \text{ kWh}} = \frac{2.5¢}{\text{kWh}} \quad (4)$$

Combining the utility costs in Equation 3 and the equipment costs in Equation 4, the total cost of air-conditioning is roughly 10 ¢/kWh. Using this figure, we calculated the costs (line 1b) of the annual U.S. air-conditioning energy use (line 1a), shown in Table 3.

**Table 3: Base case U. S. air-conditioning use and savings potential of cool surfaces and shade tree program assuming 20% of air conditioning is avoided by 2015. (some figures are rounded).**

| Year | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|
| 1 Base Case U.S. A.C. Use | | | | | |
| 1a. Electricity (BkWh) | 441 | 464 | 488 | 512 | 539 |
| 1b. $(utility + customer) cost† | $42 B | $44 B | $46 B | $49 B | $51 B |
| 1c. $CO_2$(MtC*) | 110 MtC | 116 MtC | 122 MtC | 128 MtC | 135 MtC |
| 2 Annual Savings | | | | | |
| 2a. Fraction of Base Case (%) | 0 | 5 | 10 | 15 | 20‡ |
| 2b. Electricity (BkWh) | 0 | 23 BkWh | 49 BkWh | 77 BkWh | 108 BkWh |
| 2c. $(utility + customer) cost† | 0 | $2.2 B | $4.6 B | $7.3 B | $10 B |
| 2d. $CO_2$(MtC) | 0 | 6 MtC | 12 MtC | 19 MtC | 27 MtC |

† Assuming a kWh costs 10 cents in 1994 dollars.
* MtC= million metric tons of carbon
‡ Potential savings in 20 years when re-roofing is completed and trees have matured.

Finally, to compute line 1c, the base case production of $CO_2$ due to air-conditioning use, we estimate that 250 g of carbon are associated with the marginal value of 1 kWh. Thus, the projected carbon emission from air-conditioning energy use rises from 110 MtC (million metric tons of carbon) in 1995 to 135 MtC in 2015.

Next, calculating the savings (lines 2a through 2d), we estimate that the widespread use of cool surfaces and vegetation in cities should be able to save 20% of cooling energy. Such savings would be achieved gradually, perhaps in a span of 20 years, as urban shade trees grow to maturity, and hot roofs and roads reach their scheduled maintenance. Thus, a nation-wide heat island mitigation program begun in 1995 may achieve 5% of base case savings by 2000, 10% by 2005, 15% by 2010, and the saturation value of 20% by 2015. At this maximum value, we estimate annual savings of 108 BkWh, worth $10 billion (in 1990 dollars), and preventing the emission of 27 Mt of carbon. For comparison, the recent Climate Change Action Plan released by the Clinton Administration calls for a 108 MtC reduction by the year 2000. A program of cool surfaces and shade trees can achieve 5% of this reduction in the year 2000, and 25% in 2015.

## 5. Policy Steps to Implement Cool Surfaces and Shade Trees Program

Table 3 describes the potential savings from a strong cool surfaces and shade trees program begun in 1995. However, achieving this potential is conditional on the necessary Federal support. Programs for planting shade trees already exits, but to start an effective and comprehensive program, the following 7 Outreach Steps should be taken:

1. Create test procedures, **ratings**, and labels for cool materials.
2. Assemble a cool materials **data base** made widely available to industry, utilities, contractors, architects, roofers, state and local procurement officers, consumers and communities.
3. Incorporate cool roofs and shade trees into the **Building Energy Performance Standards** of ASHRAE, CABO, California Title 24, and Air Quality Management Districts. Standards can be relatively mild if accompanied by Step 4.
4. Offer **utility rebates** or other incentives to beat the standards. This will require support by the state public utility commissions.
5. Begin **information programs** for all the groups mentioned in Step 2, and distribute information by grassroots support networks to building owners and local governments.
6. Demonstrate savings in selected "**Cool Communities,**" including Federal facilities, particularly military bases. This will require support by the local utility.
7. Establish aggressive policies for the **procurement of cool roofing materials** by Federal, State and local governments. Create "purchasing co-ops" in the Cool Communities.

Let us expand on a few of these steps.

### 5a. Ratings and Labels

An effective heat island mitigation program requires a method of rating different paints and surfacing materials according to their summer mid-day surface temperature. This information must be readily available, since the albedo of a surface depends not only on its visible reflectivity (i.e. its intuitive visible brightness), but also on its reflection of infrared light, which comprises about half of incident solar energy. Thus, a light-colored surface is not necessarily cool, and vice versa. For example, commonly used light-colored roofing materials such as "white" asphalt shingles and galvanized steel run 63 °F (35 °C) and 78 °F (43 °C) hotter, respectively, than air temperature on a sunny day.[6] On the other hand, surfaces painted with red or green acrylic paint run only ~40 °F (22 °C) hotter, even though they are not visibly bright. Research is underway at LBL to create new cool surface materials, with a choice of colors, which would be highly reflective in the infrared.

The rating of materials would avert the mistaken promotion of hot light-colored materials, and create a market for innovative cool surface materials. We are consulting with the paint/pigment, roofing, and pavement industries to create an accurate and simple test procedure for heat island mitigation surfaces. Ratings would probably include the following information:

1. Surface temperature at noon on a clear day under the midsummer sun, for example at the latitude of Los Angeles and Atlanta.
2. Longevity of the high albedo, i. e. how well does a roof shed dirt, resist mold build-up, etc.?
3. Surface temperature under standard fire conditions (reflective materials offer better protection of roofs and walls from external fires).
4. Service life (to credit the potentially longer lives of cool roofs and roads compared to surfaces exposed to diurnal thermal shock and ultraviolet radiation, and to identify low quality products).

A workshop to further develop materials testing, ratings, labels, and a product data base will by organized by LBL and the National Institute of Standards and Technology (NIST) in June 1994.

### 5b. Standards for Energy Efficiency and Air Quality

As we have mentioned above, we recommend relatively mild standards which can be met without any significant change in the appearance of the buildings and pavements. Thus we have recommended to the California South Coast Air Quality Management District that new roofs (or re-roofs) must run cooler than halfway between white paint and black asphalt, and new roadways run as cool as weathered concrete. As with ratings, national or international standards for improved energy efficiency and air quality would encourage the development and sale of new surface materials.

### 5c. Utility Incentives to Beat the Standards

Given the large savings potential of a cool surfaces and shade trees program, there is a large incentive for utilities to sponsor demand-side management (DSM) programs that promote the whitening and greening of cities. If, for example, utility DSM programs are credited with 50% of the savings achieved, and that public utility commissions permit utility stockholders to retain 10% of program savings, then Table 3 shows that in 2015 utility stockholders could earn $500 million/year. Further, if reductions in $CO_2$ are given a cash value (e.g. through avoided taxation), stockholder earnings could be even higher.

Implementation programs for white surfaces should be designed to emphasize roof types that cover the largest area in a city. Modified bitumen, asphalt shingles, and built-up roofing account for 44% of the residential roofing area in California, and 37% of the commercial area [Bretz et al., 1992]. Built-up roofing and other materials can be installed with a white reflective coating for no additional cost, while adding a coating to modified bitumen may include a small incremental cost. Since the coating of asphalt shingles is an additional expense not included in

[6] White asphalt shingles are made quite dark so as not to show dirt and mildew. Unpainted galvanized steel gets hot because metals have low emissivities, which mean that they cannot cool by radiation.

installation, and voids the warranty on the shingles, it is necessary to induce shingle manufacturers to sell high-albedo shingles which shed dirt.

As an example, suppose a residential utility rebate program concentrates on large, poorly insulated, poorly shaded, dark-roofed buildings in hot climates. The annual air-conditioning bill for such a building may be $500. Replacing the dark roof with a cool one and planting shade trees around the building could perhaps save $200/year, half of which could be credited to standards. Thus a utility DSM program could save $100/year, with a discounted value of ~$1000. Thus, an appropriate utility rebate program might offer $500, approximately 10% of the cost of a new roof.

## 6. Conclusion

Raising the albedo of urban surfaces and increasing urban vegetation are easy ways to conserve energy, save money and probably to reduce air pollution. Experiments have shown 20-40% direct energy savings by increasing the albedo of a single building, and computer simulation indicates that the indirect effects of wide-scale albedo changes will nearly double the direct savings.

At its maximum potential, a vigorous cool surfaces and shade trees program could save annually $10 billion in energy and equipment costs, and eliminate 27 million metric tons of $CO_2$ emissions. To achieve this potential, several policy steps should be taken promptly. A simple ratings scheme and accurate test procedures should be established, and recent workshops with the paint/pigment, roofing, and roadway materials industries have begun this task. Standards for new construction of buildings and roadways, and utility-sponsored incentive programs would promote the use of cool surfaces and shade trees and create new markets for their development and sale. Incentive programs should target asphalt shingle, modified bitumen, and built-up roofing. The albedo of these roofs may be changed at little or no additional cost at the time of routine maintenance. Such programs may generate earnings of $500 million/year for utility stockholders.

## Acknowledgment

This work was supported by the U.S. Department of Energy, under contract DE-AC03-76SF00098, with special support from the Sacramento Municipal Utility District (SMUD). Additional support was provided by the California Institute for Energy Efficiency (CIEE), and the Environmental Protection Agency. We acknowledge the contribution of many members of the Heat Island Project at LBL, and especially thank Debbie Giallombardo and Allan Chen for their editing and production assistance and Lynn Price for her assistance with the figures.

## References

Akbari, H, S. Davis, S. Dorsano, J. Huang, and S. Winnett (editors). 1992. Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing. U. S. Environmental Protection Agency, Office of Policy Analysis, Climate Change Division.

Akbari, H., Bretz, S. E., Hanford, J. W., Kurn, D. M., Fishman, B. L., and Taha, H. G. 1993. "Monitoring Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces in the Sacramento Municipal Utility District (SMUD) Service Area: Data Analysis, Simulations, and Results," Lawrence Berkeley Laboratory Report LBL-34411.

Akbari, H., Rosenfeld, A., and Taha, H. 1989. "Recent Developments in Heat Island Studies, Technical and Policy," *Proceedings of the Workshop on Urban Heat Islands*, Berkeley CA, (February 23-24).

Akbari, H., Rosenfeld, A., and Taha, H. 1990. "Summer Heat Islands, Urban Trees, and White Surfaces," *Proceedings of American Society of Heating, Refrigeration, and Air*

*Conditioning Engineers*, Atlanta, Georgia, (February); also Lawrence Berkeley Laboratory Report LBL- 28308.

Arritt, R. W. 1985. "Numerical Studies of Thermally and Mechanically Forced Circulations Over Complex Terrain." Cooperative Institute for Research in the Atmosphere, Colorado State University, For Collins, CO.

Bretz, S., Akbari, H., Rosenfeld, A., and Taha, H. 1992. "Implementation of White Surfaces: Materials and Utility Programs," (draft), Berkeley, CA: Lawrence Berkeley Laboratory Report LBL-32467.

Competitek/E-Source 1992. *State of the Art: Space Cooling and Air Handling*. Competitek has changed its name to E-Source, Boulder CO, 80302 (303) 440-8500.

Mahrer, Y. and R. A Pielke. 1977. "A Numerical Study of the Air Flow over Irregular Terrain." *Contr. Atmos. Phys.*, **50**, pp. 98-113.

Mahrer, Y. and R. A Pielke. 1978. "A Test of an Upstream Spline Interpolation Technique for the Advective Terms in a Numerical Mesoscale Model." *Monthly Weather Review*, **106**, pp. 818-830.

Means Company. 1990. *Means Building Construction Cost Data, 1991: 49th Annual Addition*, Kingston, MA: Construction Consulting and Publishing.

National Roofing Contractors Association. 1990. Miscellaneous sales records provided to LBL. NRCA, Rosemont, IL, (708) 299-9070.

Parker, D.S., Cummings, J.B., Sherwin, J.S., Stedman, T.C., and McIlvaine, J.E.R. 1993. "Measured A/C Savings from Reflective Roof Coatings Applied to Florida Residences," Florida Solar Energy Center FSEC-CR-596-93, February 1993. Florida Solar Energy Center, Cape Canaveral, FL.

Parker, D.S., S. F. Barkaszi, and J. K. Sonne. 1994. "Measured Cooling Energy Savings from Reflective Roof Coatings in Florida: Phase II Report." Contract Report FSEC-CR-699-95. Florida Solar Energy Center, Cape Canaveral, FL.

Rosenfeld, A., H. Akbari, H. Taha and Bretz, S. 1992. "Implementation of Light-Colored Surfaces: Profits for Utilities and Labels for Paints," presented at the *American Council for an Energy Efficient Economy 1992 Summer Study on Energy Efficiency in Buildings*, Asilomar, CA. Washington, DC/Berkeley, CA: ACEEE.

Sailor, D. J. 1993. *Role of Surface Characteristics in Urban Meteorology and Air Quality.* University of California Ph. D. Thesis UC-402 and Lawrence Perkeley Laboratory Report LBL-34459.

Sailor, D.J. and Kessler R. 1993. "Chapter 4.3: Three Dimensional Simulation Results," in *Analysis of Energy Efficiency and Air Quality, Interim Report*, pp. 4.57-4.82, Lawrence Berkeley Laboratory Report LBL-33051.

Taha, H., D. Sailor, and Akbari, H. 1992. "High-Albedo Materials for Reducing Building Cooling Energy Use," Berkeley, CA: Lawrence Berkeley Laboratory Report LBL-31721.

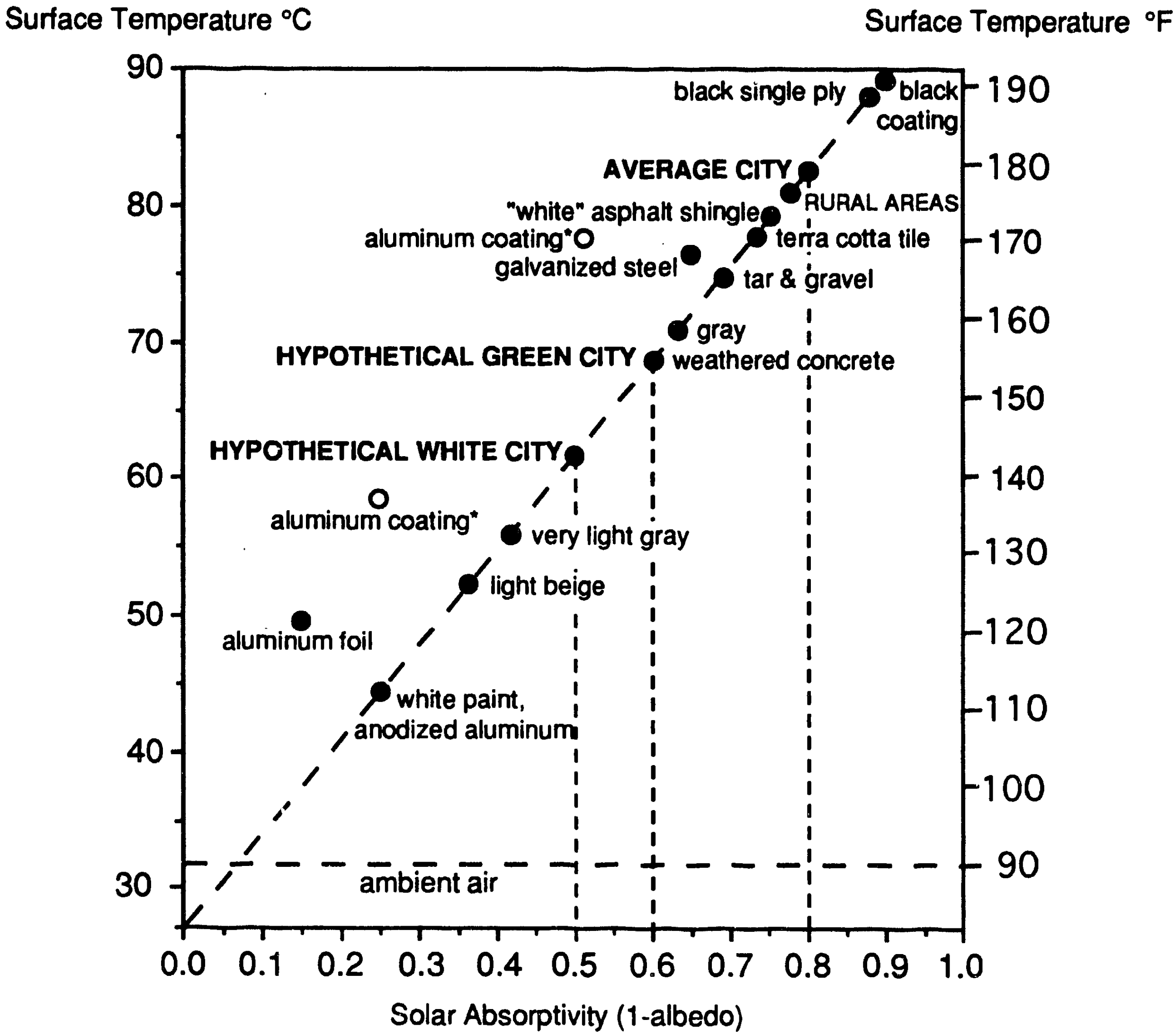



Figure 1: Surface temperature vs. solar absorptivity of horizontal surfaces of paints, roofing materials, roadways and cities, adjusted to noon on a clear and windless summer day in Austin, Texas. Outside ambient air temperature is 32°C (90°F). Surface temperatures of white and black surfaces can vary as much as 45°C. Different paving materials (asphalt and concrete) differ by 20°C. Metals become hotter than similar colored paint because they radiate poorly (low thermal emissivity). The average surface temperature of q typical city is over 80°C. A hypothetical light-roofed "green city" with white roofs, light streets and parking lots, and urban vegetation has average surface temperature 14°C lower than that of a typical city. In the hypothetical "white city" with less urban vegetation (appropriate for arid areas), surface temperature is further reduced. Reduced surface temperature and increased vegetation results in lower air temperatures [Taha, Sailor and Akbari, 1992].

* The absorptivity of aluminum coatings ranges from 0.2 to 0.5.

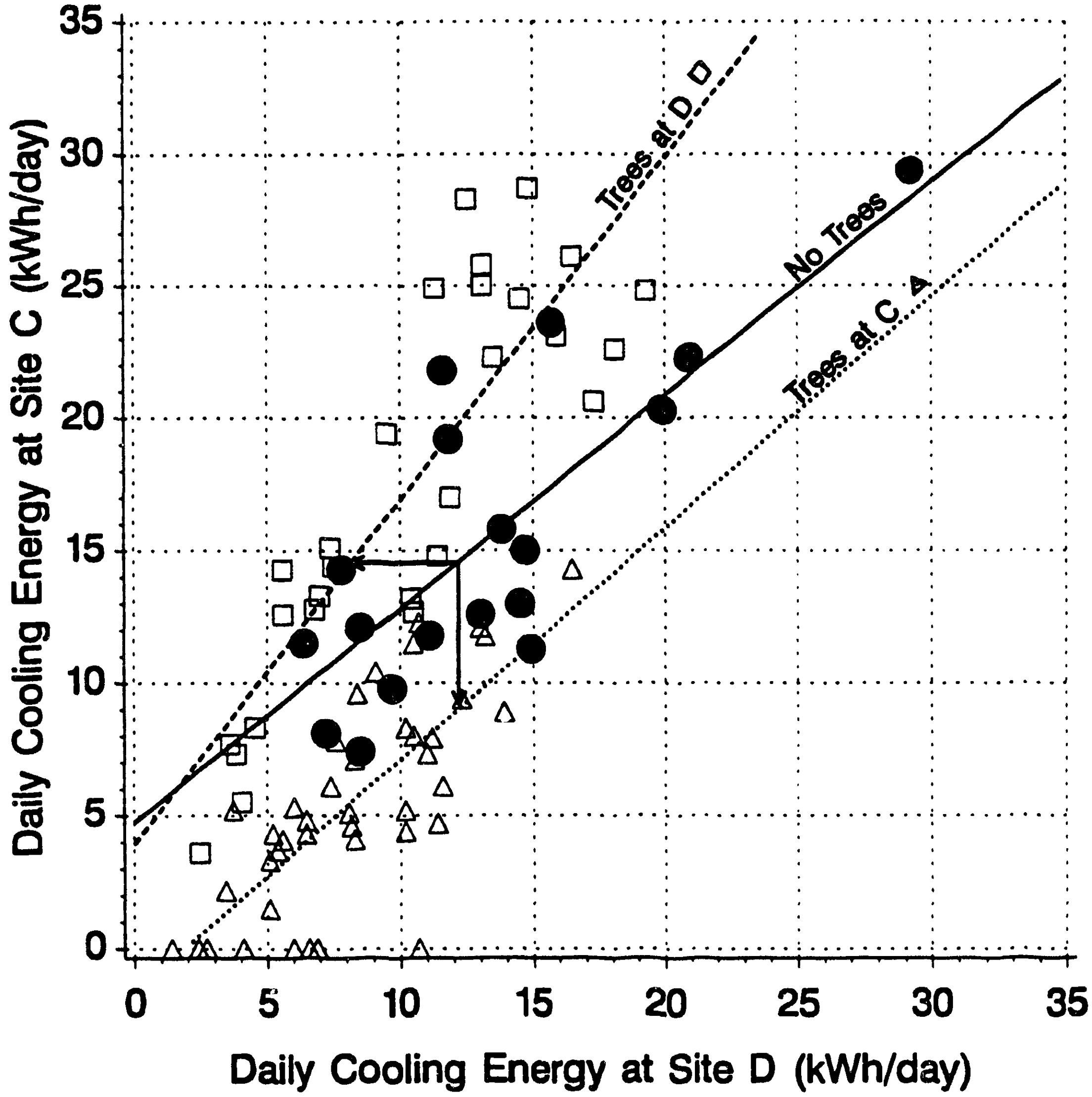



Figure 2: Energy consumption changes due to shading by eight large and eight small trees of two houses in Sacramento, CA. Dots and their solid regression line represent 19 July base case days with no trees. Squares show the next 20 August days with Site D shaded. These data and their dashed regression move **left** about 35%. Triangles show 39 September and October days with the trees moved to Site C. These data move **down**, again by about 35%. Shading saves 4-5 kWh/day.

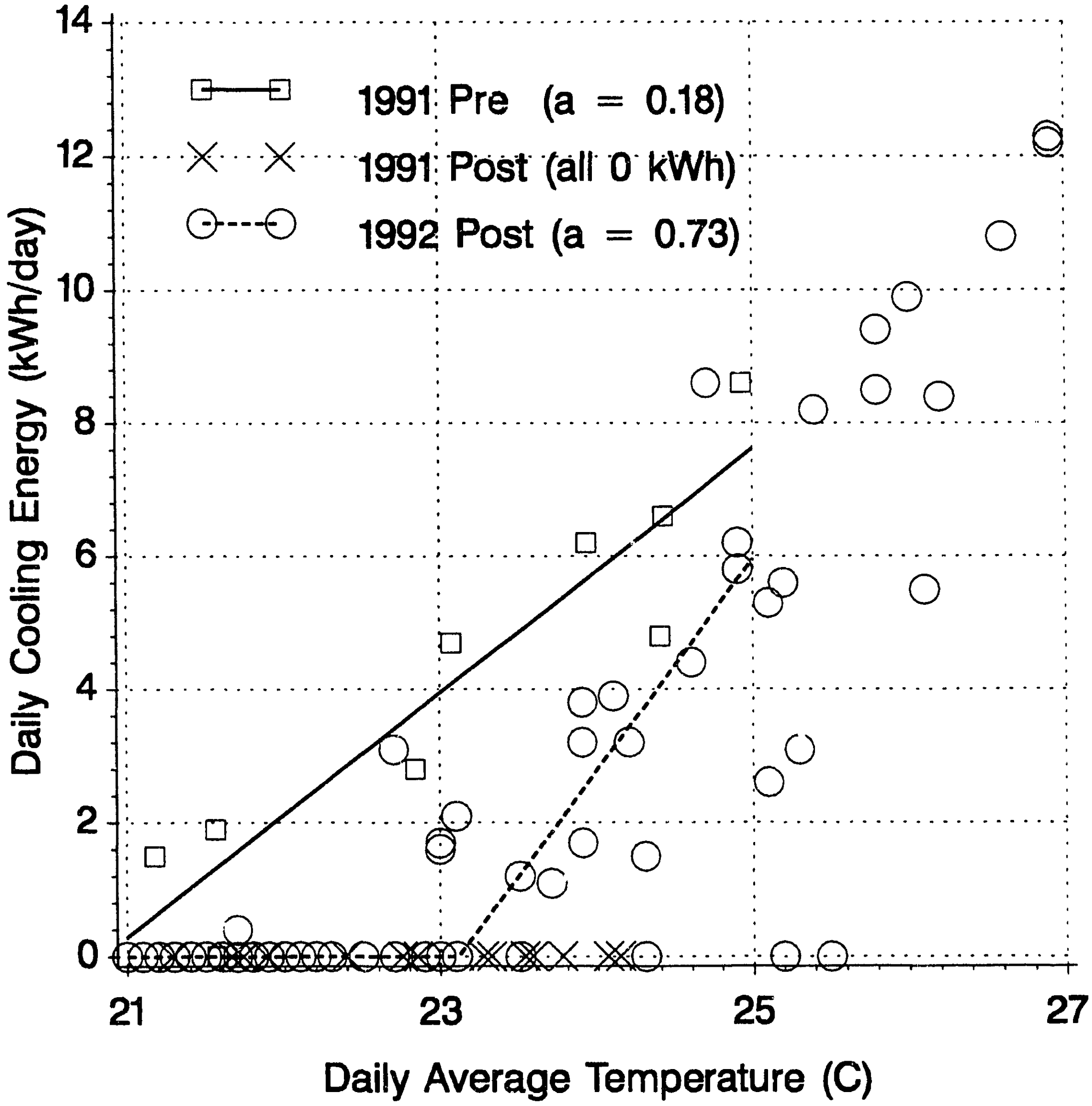



Figure 3: Daily cooling energy use at a house in Sacramento, CA versus daily average outdoor temperature. The squares and their solid regression line represent pre-modification conditions, when the roof was dark, with an albedo of 0.18. The X's represent data collected after the roof albedo was raised to 0.78 with a high-albedo coating. No air-conditioning was used during this period. The circles, many of them at 0.0 kWh/day, represent the post-modification period when the roof was washed and its albedo restored to 0.73. The dotted line represents a regression to the data between 23 °C and 25 °C. Below this range, no cooling energy is used. Above this range, there are no pre-modification data. Lines indicate savings of 1.5 to 4 kWh/day [Akbari et al., 1993].

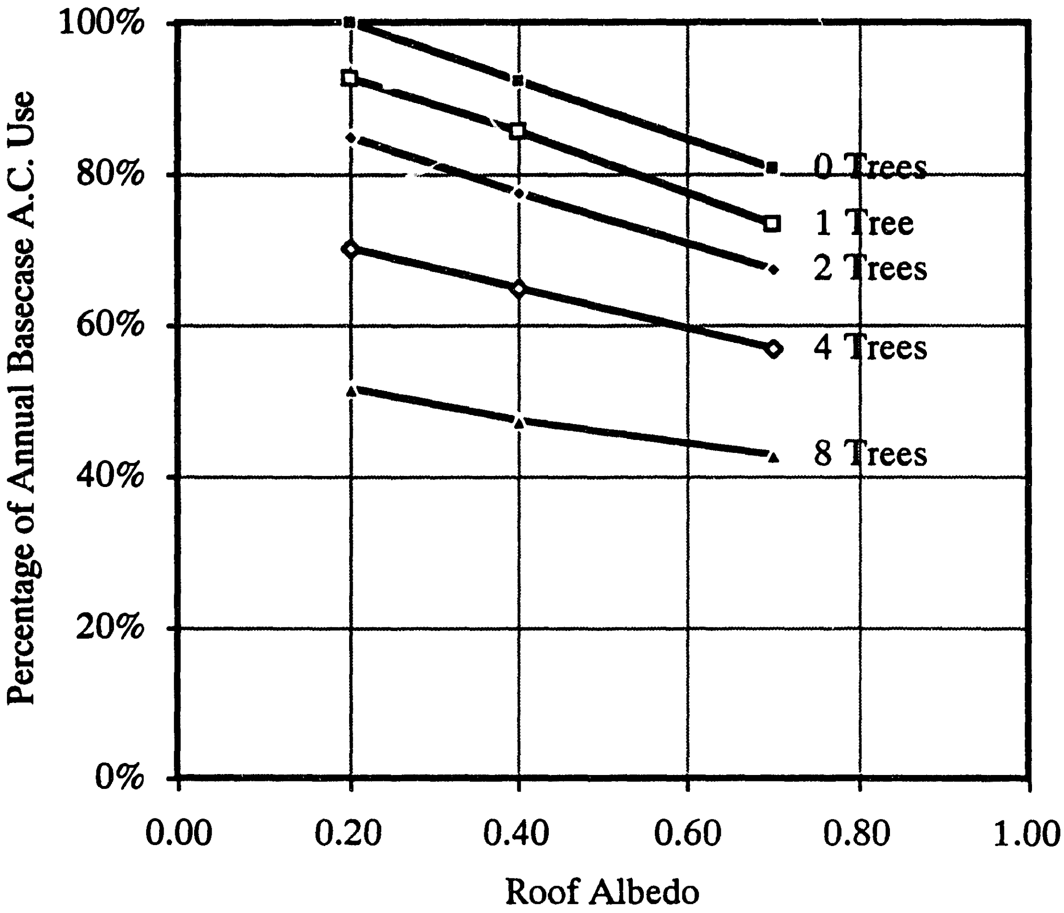



Figure 4: DOE-2.1E simulation of the percentage of base-case annual air-conditioning energy used by a building prototype in Sacramento, CA for combinations of albedo modification and tree shading. The building prototype describes a new house with an R-30 roof, R-11 walls, double-glazed windows,a vaulted ceiling, and no duct system. Roof and wall albedos were increased from their initial values in two increments. The number of shade trees was increased from zero to eight trees in four increments. Weather data were obtained from the National Climate Data Center for a weather station at Sacramento Executive Airport. Other simulations suggest that these energy savings are underestimated by as much as twofold.

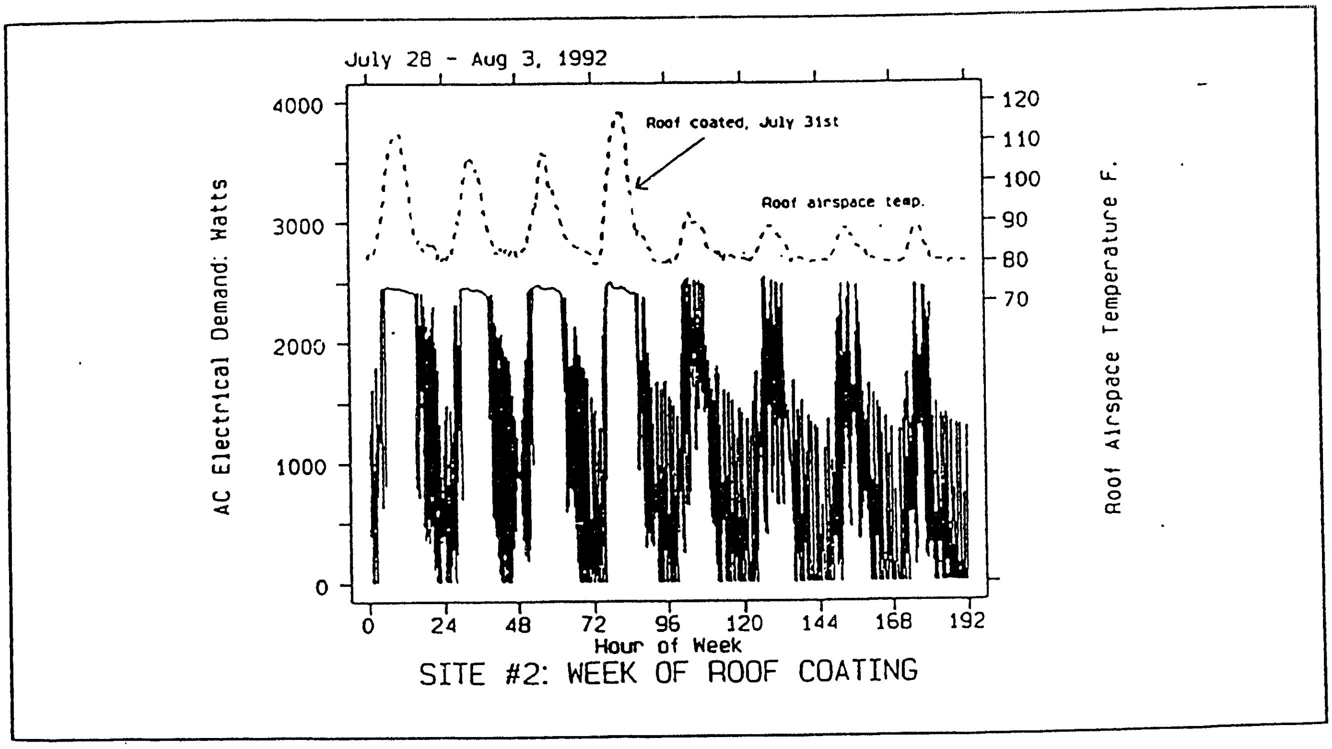



Figure 5: Roof air space temperature and 15-minute air-conditioning consumption of a test house with R-11 roof insulation in Florida between July 28 and August 3, 1992. The roof was treated with a reflective roof coating on July 31st. Both roof temperatures and cooling energy consumption were substantially reduced. Air conditioning electricity use was decreased by 43% over periods with similar weather conditions [Parker et al., 1993].

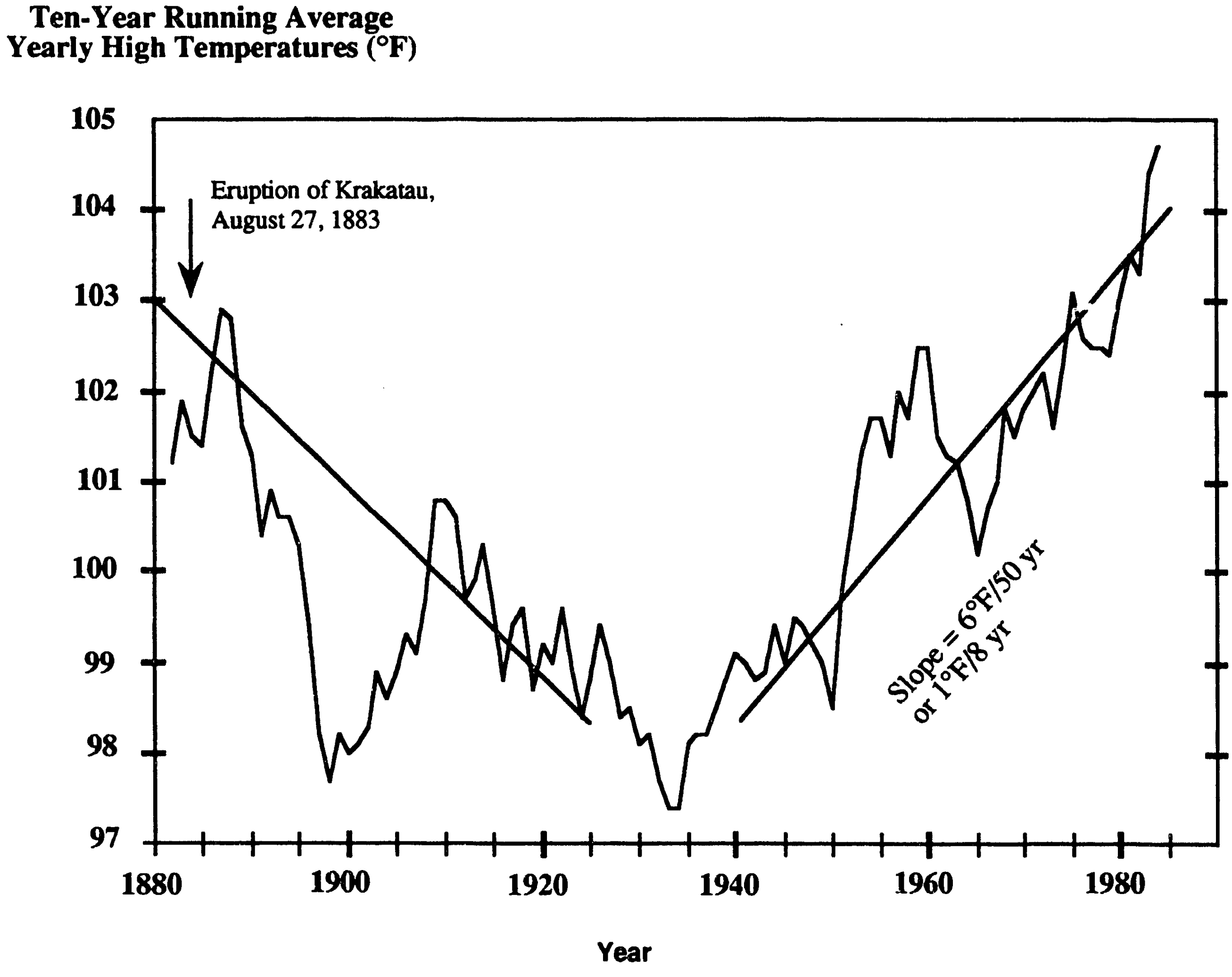



Figure 6: Ten-year running average high temperatures in Los Angeles, CA (1882 - 1984). With increasing irrigation and orchards, Los Angeles cooled 2°C/year until the 1930s. Then, as asphalt replaced trees, Los Angeles warmed 3°C (6°F) to 1980. The ten-year running average is calculated as the average temperature of the previous 4 years, the current year, and the next 5 years. The pronounced temperature depression in the late 1880s-90s is due to the eruption of the Krakatau volcano.

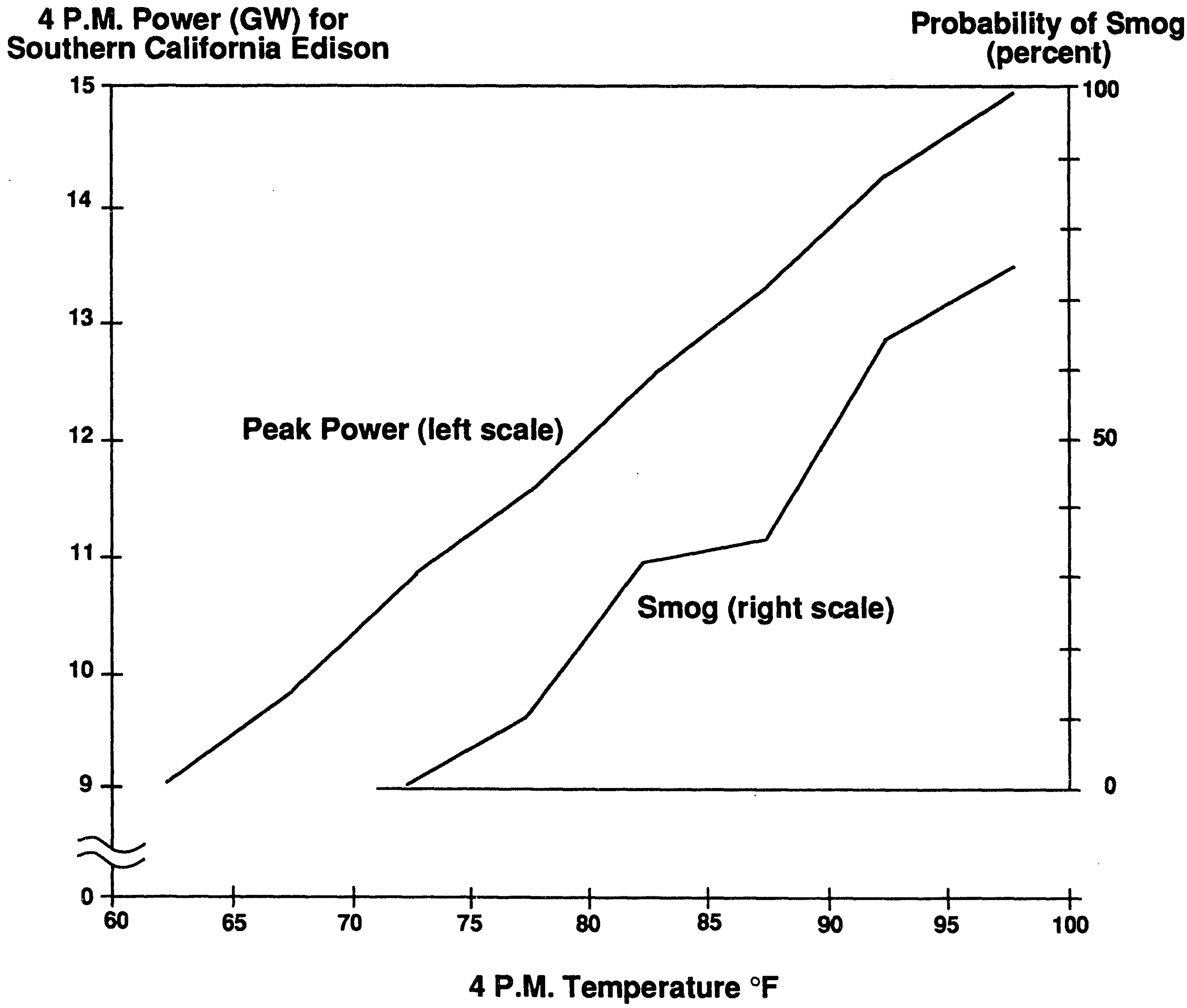
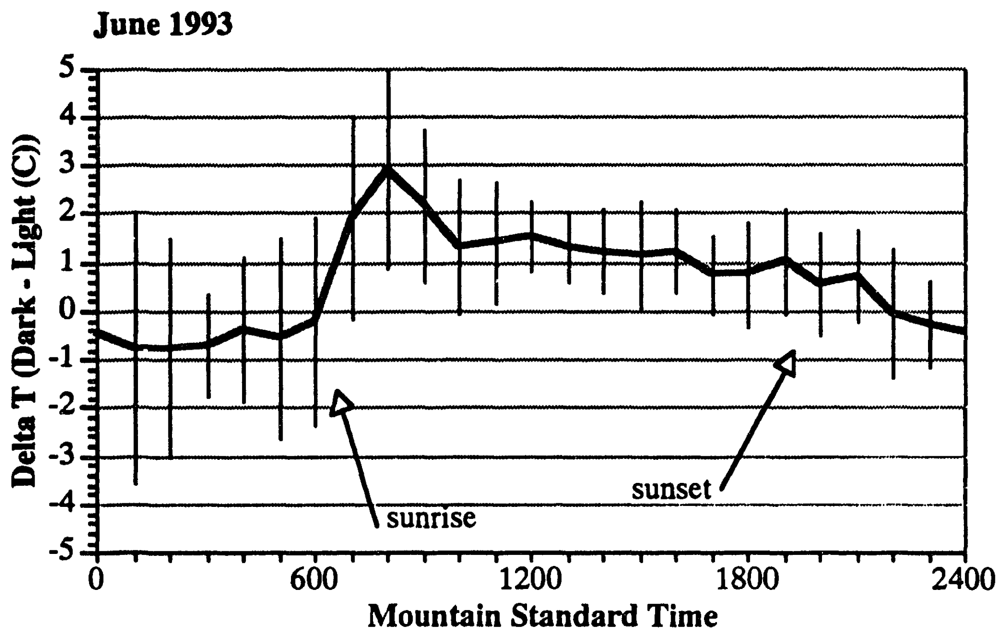



Figure 7: Ozone levels and peak power for Southern California Edison vs. daily maximum temperature in Los Angeles, CA. Peak power use rises by 3% for every 1°C rise in daily maximum temperature. Probability of smog increases by 5% for every 1°C rise in daily maximum temperature above 70°F (21 °C) [Akbari et al., 1990].



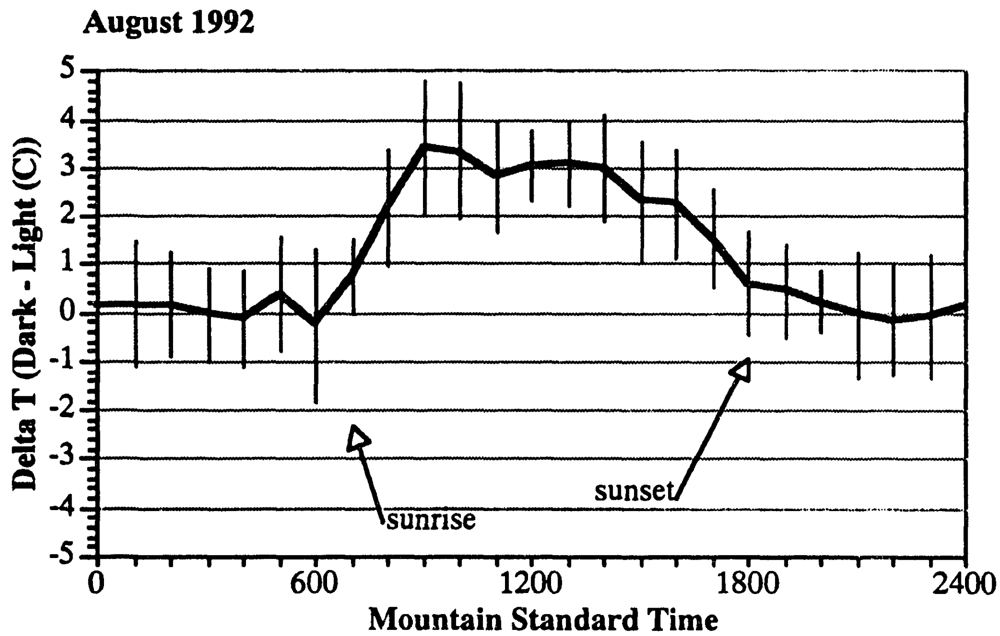




Figure 8: Difference between dry-bulb air temperatures measured at weather stations installed over light and dark areas of White Sands National Monument averaged by hour for both June 1993 and August 1992. Vertical lines represent one standard deviation from the mean. Includes only non-rainy days. Temperature difference achieves a maximum of ~3°C in the morning hours. Later in the day, the temperature difference drops as vertical upwelling increases.

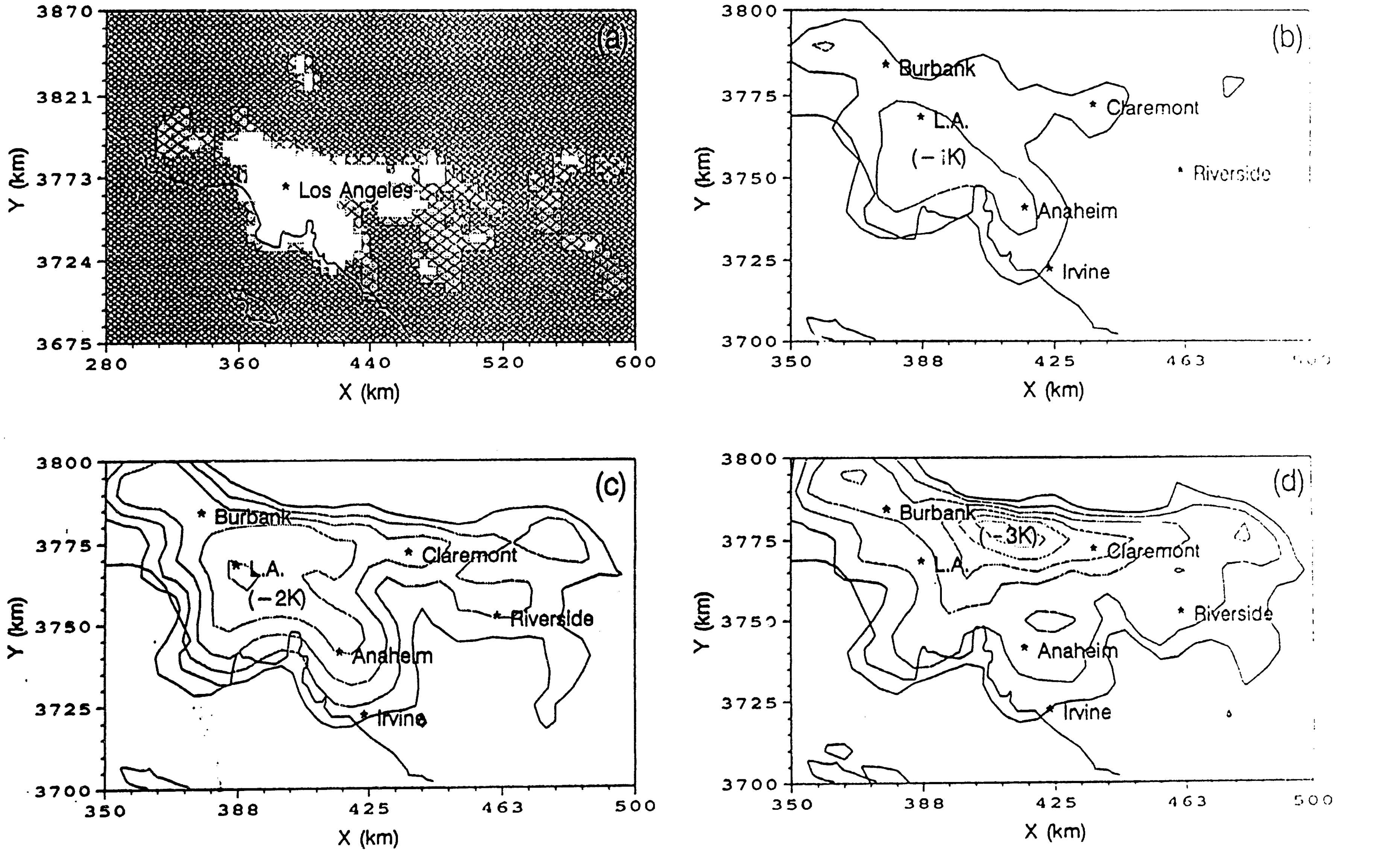



**Figure 9** Albedo modification results: (a) Regions within the modeling domain which have been identified for simulated albedo augmentation. Grey is unmodified, hashed is a modification of less than 0.10, and white is a modification in excess of 0.10. The average albedo increase over the 394 modified cells is 0.16; (b) temperature difference between high-albedo case and base case simulation at 9 a.m. (c) same as b except at noon; (d) same as b except at 3 p.m. Contour increment in b–d is 0.5 deg. C.

## ATTACHMENT 2

Presentation Summary from Danny S. Parker
Florida Solar Energy Center

Danny Parker is Senior Research Scientist at FSEC. This attachment provides a brief overview of Danny's work with cool building materials at FSEC.

**Measured Cooling Energy Savings From Reflective Roof Coatings in Florida**

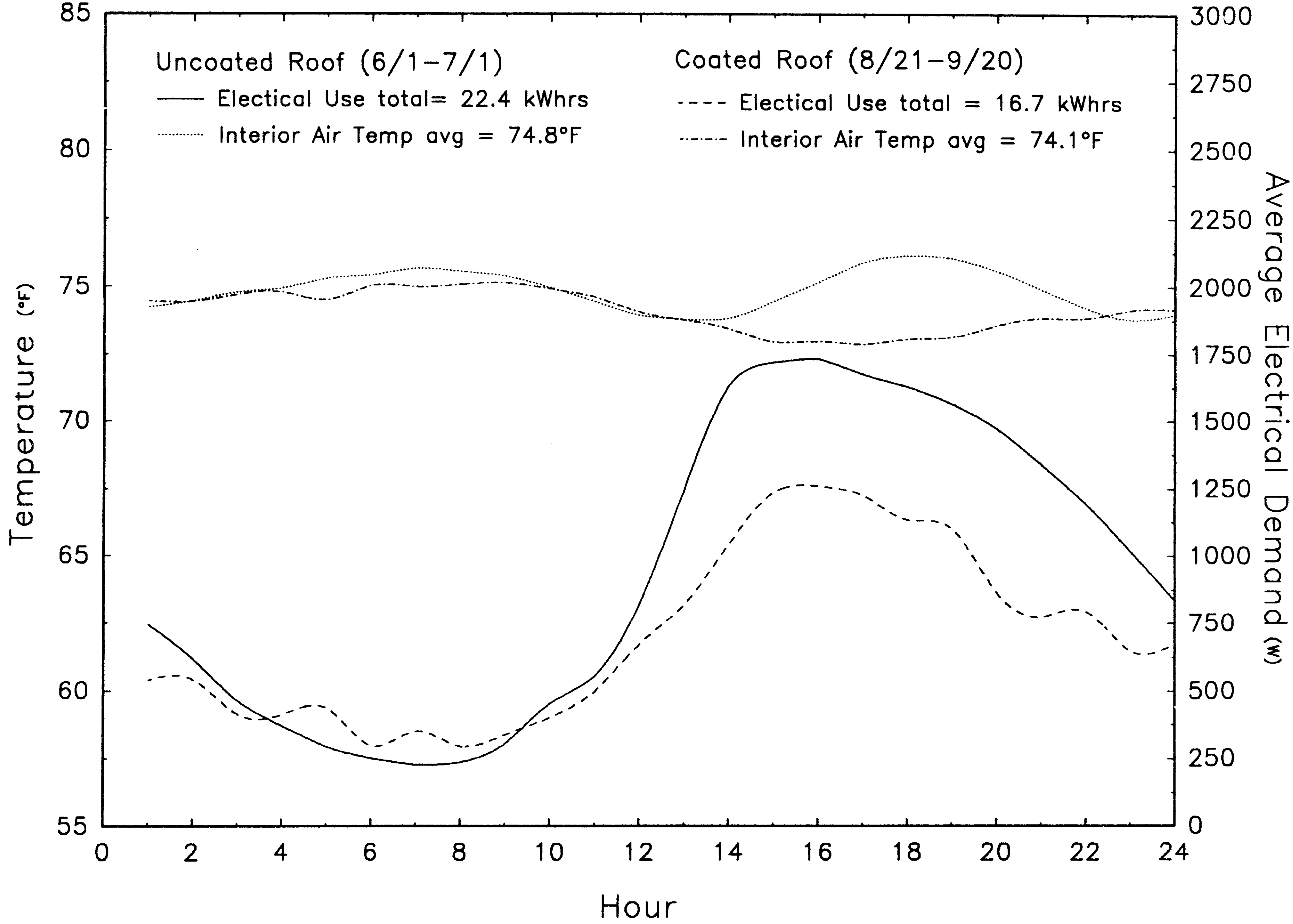
Danny S. Parker
Cool Building Materials Workshop
NIST/Gaithersburg
February 28, 1994

Traditionally architects in hot climates have recognized that light building colors can reduce building cooling needs. However, until recently, there has been little empirical data quantifying potential impacts. To address this need Florida Solar Energy Center has conducted field research over the last two years to measure the impact of reflective roof coatings on sub-metered air conditioning (AC) energy use. Tests have been performed on six occupied homes. The roof types in the study homes varied. Three had asphalt shingle roofs, one was a modified bitumen roof and the others had a gravel and barrel tiled roof. The coatings were applied to the roofs of each residence at mid-summer after a month-long period of monitoring during which meteorological conditions, building temperatures and AC energy use were recorded every 15 minutes. Thermostat settings and other occupancy related conditions were held constant during the tests.

Data analysis revealed significant reductions in space cooling energy subsequent to the roof whitening at all sites. Using weather periods with similar temperatures and solar insolation, air conditioning energy use was reduced by 11% - 43% in the homes. The average savings in space cooling energy use was 9.2 kWh/day or 23% of the pre-application air conditioning consumption. Utility coincident peak electrical demand reduction between 5 and 6 PM varied between 444 and 988 W at the sites (16%-38%), averaging 689 W or 27%. Recorded temperatures and infrared thermography revealed large changes to the roof-attic thermal performance in the buildings examined. As expected, the savings roughly tracked the degree of ceiling insulation. The greatest reductions were achieved in the most poorly insulated attic assemblies.

Figure E.1 shows how the average roof surface, decking and attic air temperature profiles were reduced by the reflective roof coating at one of the sites in West Florida. Figure E-2 shows the comparative air conditioning electrical demand profile and interior temperatures before and after the application. Space cooling energy use was reduced by 25% while attaining improved interior comfort conditions.

The investigators conclude that the use of reflective roofs in Florida represents an effective method to reduce residential space cooling energy needs. The data suggest that air conditioning savings of 10-40% can be realized, with the larger reductions associated with poorly insulated roof assemblies or buildings with excessive attic air infiltration due to air handler return air leakage. Reflective coatings may be particularly appropriate for existing Florida residences in which the roof structure makes it difficult to retrofit insulation.


Uncoated Roof (6/1–7/1)
Electical Use total= 22.4 kWhrs
Interior Air Temp avg = 74.8°F
Coated Roof (8/21–9/20)
Electical Use total = 16.7 kWhrs
Interior Air Temp avg = 74.1°F
Temperature (°F)
Average Electrical Demand (W)
Hour
85
80
75
70
65
60
55
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
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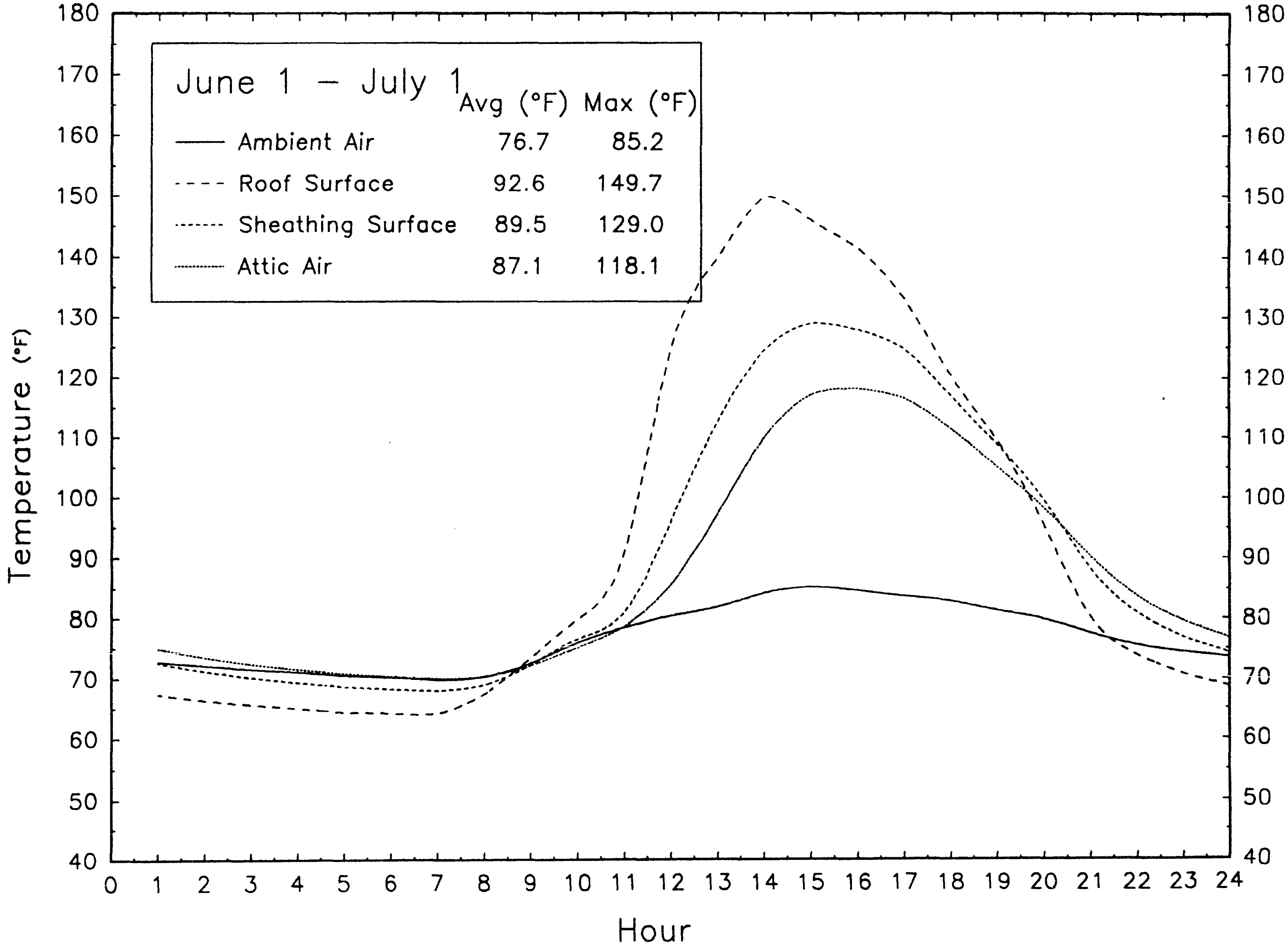
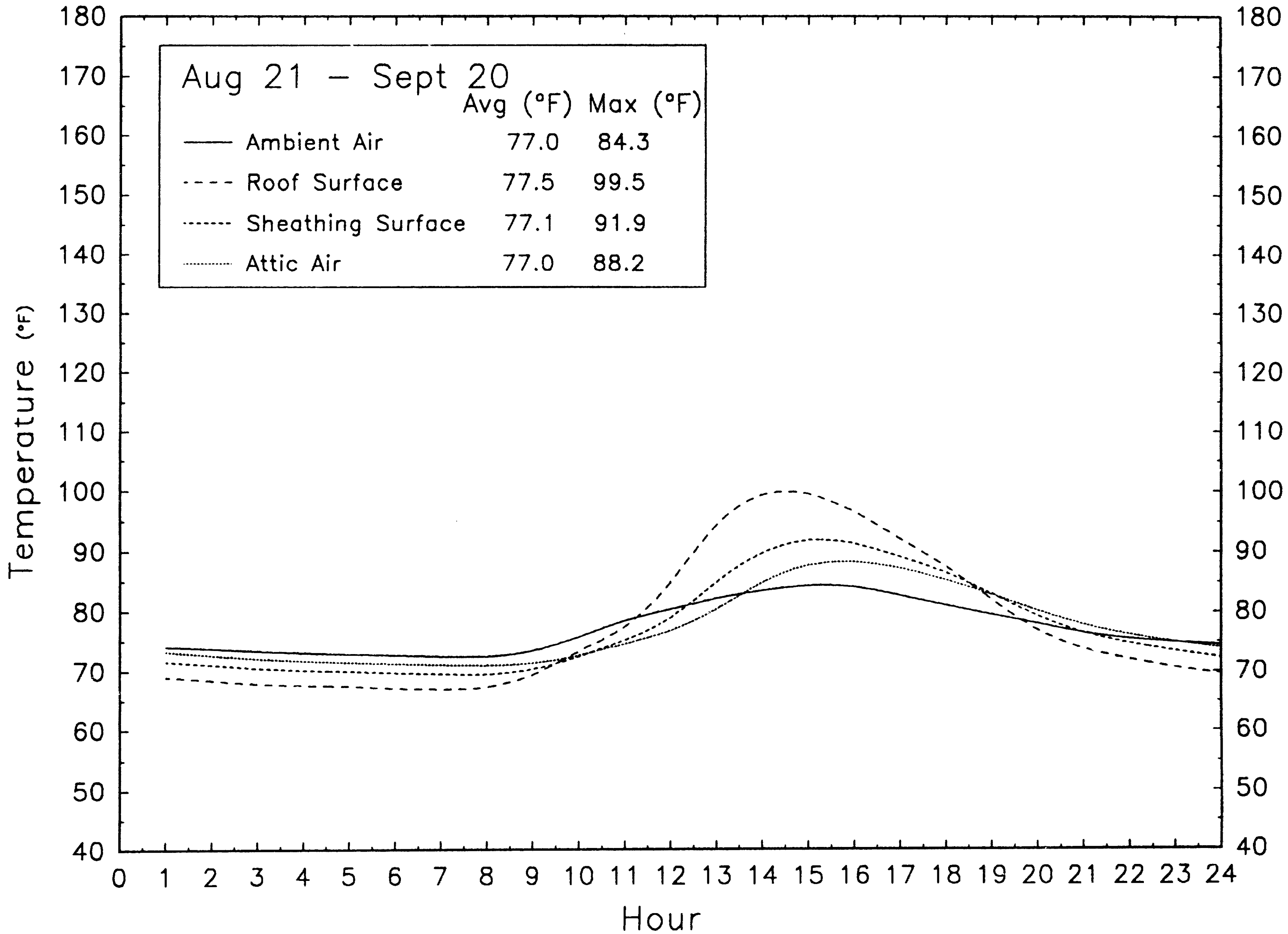

June 1 – July 1
Avg (°F) Max (°F)
Ambient Air 76.7 85.2
Roof Surface 92.6 149.7
Sheathing Surface 89.5 129.0
Attic Air 87.1 118.1
Temperature (°F)
Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
40 50 60 70 80 90 100 110 120 130 140 150 160 170 180


Aug 21 – Sept 20
Avg (°F) Max (°F)
Ambient Air 77.0 84.3
Roof Surface 77.5 99.5
Sheathing Surface 77.1 91.9
Attic Air 77.0 88.2
Temperature (°F)
Hour
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

## ATTACHMENT 3

Letter from Bruce Vincent, Sacramento Municipal Utility District

Bruce Vincent is a Senior Demand Side Specialist at the Sacramento Municipal Utility District. SMUD has shown a strong interest in creating utility incentive programs for these materials. Bruce is very involved in developing these programs. Although he could not attend the meeting he sent this letter to show his support.

**SMUD**
SACRAMENTO MUNICIPAL UTILITY DISTRICT ☐ P. O. Box 15830, Sacramento CA 95852-1830, (916) 452-3211
AN ELECTRIC SYSTEM SERVING THE HEART OF CALIFORNIA

February 23, 1994
ART 94-035

Mr. Art Rosenfeld
Lawrence Berkeley Laboratory
1 Cyclotron Road, 90-3058
Berkeley, CA 94720

Dear Art:

I will not be able to attend Monday's meeting in Washington. I apologize for this but: I'm recovering from a bout of Guillain-Barre' syndrome (in English, ascending paralysis); I'm struggling to get caught up at work; and we have a one-month-old baby at home. Of the aforementioned, the baby and the resulting sleep deprivation are the most debilitating.

The research project recently completed by SMUD and LBL goes a long way towards verifying the direct benefits of white roofs and shade trees. Nevertheless, there is still a great deal of work to do:

- The database on the energy impacts of white roofs is very small for both the residential and commercial sectors. More monitoring and analysis is needed.
- The durability of reflective roofing products appears to vary greatly, even for what are billed as similar products.
- The long-term effects of dirt are relatively unknown.
- There is very little data on indirect effects. Indirect effects will provide cooling load reductions and these benefits will eventually need to be factored into benefit/cost calculations for utility rebate programs.
- The effect of white roofs on heating loads is unknown. I suspect that the effect is insignificant for most buildings, but monitoring and analysis are needed.
- Non-white, highly-reflective products are needed for the residential sector.
- While there are light colored conventional roofing products (e.g. tile, composition), there appears to be room for improvement.



DISTRICT HEADQUARTERS ☐ 6201 S Street, Sacramento CA 95817-1899

- Fraudulent products sometimes appear on the market.

- Very little work has been done with light-colored pavement, parking lots and driveways.

- Existing computer models fail to accurately predict cooling load reductions for white roofs. I suspect that they almost always under-predict and that the reasons for this are: outdated algorithms; failure to include impacts on air-distribution systems; and not including radiant effects.

White roofs will be a big winner for urban summer-peaking utilities like SMUD if they can be widely implemented. Highly reflective white roofs are likely to become the standard in the commercial sector. In addition, there is significant potential for white roofs in the residential market (white tile, etc in new construction and white coatings for rehabilitating shake and composition roofs.)

The roof-products industry can assist utilities that would like to promote white roofs. A testing and labeling program would be very helpful. Labels should include the following information: (1) reflectivity in both the visible and the infrared; (2) a measure of the long-term effects of weathering; and (3) an indicator of the material's ability to resist the accumulation of dirt; and (4) an indicator of the material's cleanability.

Again, I offer my apologies for not being able to attend. I am looking forward to working with LBL on future projects.

Sincerely,

Bruce A. Vincent
Senior Demand Side Specialist

## ATTACHMENT 4

Presentation Summary from Paul Berdahl
Lawrence Berkeley Laboratory

Paul Berdahl is an applied solid state physicist at LBL. The following attachment is a summary of Pauls research on the spectral reflectance of roof coatings. This work is of key importance for the development of better cool building materials.

# Technical Issues for the Development of Cool Building Materials

Paul Berdahl
Cool Building Materials Workshop
Gaithersburg, MD
February 28, 1994

The work reported here was performed by Paul Berdahl
and Sarah Bretz as part of DOE's
Cool Communities/Heat Island project
at Lawrence Berkeley Laboratory

This presentation focused on the technical issues which involve radiant energy exchange between the building skin, especially the roof, and its environment. The radiative performance depends on the optical properties and the morphology of the materials used.

The **slide 1** is an approximate color image of most of the samples discussed in the following presentation. They were mounted on an insulating board with thermocouples underneath each sample. Thus, when this insulating board was exposed to the sun, the sample temperatures could be monitored. The listed temperatures were observed in Berkeley, California, on a clear day in November. (The board was tilted to be normal to the sun's rays, to maximize the temperatures. As a result of this tilt, the samples viewed radiation reflected and emitted from the foreground.) The samples consisted of samples of "typical" roofing materials such as shingles, and other samples which might be representative of future, cooler materials. Also used was a typical black, and an optical grade white ("hyper" white). The black gets as hot as possible (for a surface with high infrared emittance), and the optical white is the coolest material available.

The spectral distribution of solar radiation, and that of the long-wave radiative cooling is depicted on **Slide 2**. The vertical scale is arranged so that equal areas under the curves represent equal energy flows in W m-2 over a 24 hour period; the box shows 100 W m-2. The surface under consideration is a horizontally exposed black surface (e.g., a roof). Atmospheric conditions were assumed to be typical clear sky conditions. The radiative cooling shown by the solid curve assumes that the average surface temperature is equal to the average air temperature; most of the cooling occurs in the so-called atmospheric window between 8 and 13 micrometers wavelength. The dashed curve shows the cooling for an emissive surface which averages 20°C above air temperature.

An expanded version of the solar spectrum is shown in **Slide 3**. This spectrum includes contributions from both the direct beam sunlight and the diffuse skylight. This spectrum shows the ASTM standard solar spectrum (E892), which is for air mass 1.5 (solar zenith angle of 48°). The near infrared region of the spectrum contains about half of the energy flow. The ultraviolet (UV) portion of the spectrum is not too important from an energy conservation point of view, but these energetic photons cause damage to organic materials and in fact strongly limit the lifetimes of many materials exposed to the sun (especially roofs). The major absorption features in the near infrared portion of the spectrum are due to atmospheric water vapor. This spectrum will be shown together with spectral reflectances in what follows, so the reader can keep in mind the relative importance of the different parts of the spectrum.

**Slides 4 and 5** show the spectral reflectance of a black acrylic paint and asphalt. These black materials show no spectral features, and exhibit reflectances of only 4 to 5%. Thus they are "ideal" black materials and would be good coatings for solar absorbers but of course are poor coatings for a roof on a building in a hot climate zone.

The black acrylic with XIR film (**Slide 6**) is the black acrylic paint covered with a solar control film developed for use on windows. This XIR film is 60% transparent in the visible spectrum (30% absorption, 10% reflection) and rather reflective in the near infrared. Thus despite its black appearance, it can remain about 19°F (11°C) cooler than the ordinary black in sunlight. This material illustrates the fact that the visible appearance (i.e., black) can be maintained even while improving the solar reflectance.

The white acrylic paint (**Slide 7**) is typical of a practical but high quality coating based on titanium dioxide (rutile) pigment in a transparent polymer binder. The strong absorption in the UV is due to the rutile pigment, and is regarded as a favorable feature because the absorption of the UV helps to protect the polymer. Pigment manufacturers optimize the particle size to obtain the highest possible reflectance in the middle of the visible range at 550 nm (0.55 micrometers). The optimum particle size is about 200 nm. In this case the visible reflectance is over 90% However the solar reflectance is only 83%. It could be raised some by the use of larger particles, say 260 nm, which would raise the reflectance in much of the near infrared. There are also some absorption features in the near infrared, which are due to vibrations of hydrogen atoms in the coatings. The strong (but unimportant) absorption near 2.3 micrometers is due to C-H bonds in the polymer. Some of the other absorption features, such as the dip at 1.7 micrometers, are also due to the polymer, but others are most likely due to hydrogen atoms in OH groups and $H_2O$. The specialty white material (**Slide 8**) is used in optics for integrating spheres, laser pump cavities, etc. It is a pressed powder of tetrafluoropolyethylene. While this porous material is not suitable as a building material, it shows that the 80 plus percent reflectance of a good white paint still offers plenty of room for improvement.

The cementitious coating (**Slide 9**), with a solar reflectance of 71%, is clearly useful for practical control of solar absorptance. On the other hand, the "white" asphalt shingle (**Slide 10**) has a solar reflectance of only 24%.

Galvanized steel (**Slide 11**) is one of the worst materials for keeping a structure cool. The solar reflectivity is only 36%, and the infrared emissivity is very low. The aluminum roof coating (aluminum particles in a dark binder) has a higher solar reflectance (52%), and a somewhat higher infrared emittance. Thus it is certainly superior to galvanized steel, but is of course inferior to a good white coating.

The green asphalt shingle (**Slide 12**) has an even lower reflectance than the white asphalt shingle. Its solar absorptance of 86% is not all that different from that of black at 95%. The low reflectance is attributed to the black asphalt substrate material and to the surface roughness.

That is, multiple scattering caused by the granules on the substrate increases solar absorption. The coatings on the granules of the green asphalt shingle are believed to be primarily chromium oxide (green) and titanium dioxide (white). It is interesting to see that the same materials can be used as pigments in a much more reflective coating. **Slide 14** shows the reflectance of a paint prepared with chromium oxide and titanium oxide pigments. Several of the spectral features are similar to those for the green shingle, but the overall reflectance is much higher, at 48%. Slide shows the same chromium oxide pigment, without any titanium dioxide, over a black substrate. This figure shows that this green pigment is itself quite reflective in the infrared (i.e., the white is not required for high infrared reflectance). The gradual decline of the reflectance at long wavelengths suggests that the chromium oxide particles are too small for optimum infrared reflectance; further improvements should be possible with larger particle size.

The red (terra cotta) clay tile (**Slide 15**) shows infrared reflectance which is larger than the red reflectance (near 650 nm), and the overall reflectance of 33% is not bad for such a relatively dark material. A similar spectrum may be seen in Parker et al.'s Florida Solar Energy Center report (FSEC-CR-670-93), for red concrete tile. The spectral similarities are due to the presence of the red iron oxide compound hematite, in both cases. A red paint, formulated with hematite and rutile pigments (**Slide 16**), is slightly more reflective in the red than our tile, almost as dark in the blue (400-500 nm), and achieves an overall solar reflectance of 43%. Like the chromium oxide, **Slide 17** shows that hematite has the capability to reflect the near infrared without the benefit of titanium dioxide. Similarly, it appears that the infrared reflectance can be improved by the use of larger hematite particles. **Slide 18** summarizes the results of direct temperature measurements in sunlight. These temperature rise values are the same as those listed on the cover slide (temperature rise = temperature - air temp.). They are plotted vs. the measured overall solar absorptance. The three open circles represent the samples with emissivity significantly less than the typical figure of 0.9 observed for most materials: from left to right the open circles represent the aluminum coating, the galvanized coating, and the XIR film on black. Excluding these samples, we see the excellent expected correlation of temperature with solar absorptance. The solid circles from left to right represent the hyper-white, white acrylic paint, white cementitious coating, green acrylic paint, red acrylic paint, red clay tile, white asphalt shingle, green asphalt shingle, and black acrylic paint.

An experiment was conducted to illustrate the effect of roughness. The same aerosol coating was placed on a smooth glass slide (**Slide 19**) and on a rough asphalt shingle (**Slide 20**). At each wavelength and overall, the reflectance on the rough surface was only about 75% of the value achieved for a smooth surface.

Several items of available and unavailable information were summarized. (These lists are not intended to be complete.) A great deal of information is available for calculating optical properties of materials. Often the needed optical properties (real and imaginary part of the refractive index) of pure materials are available in the literature, and the scattering from, e.g., pigment particles in a film can be computed using the well-known Mie theory. The ability to perform these calculations means that numerical "experiments" can be used to help develop improved materials.

Several types of information which do not appear to be available were listed. In general the industrial knowledge base of companies producing building materials is not very well represented in the open literature. This is in contrast, for example, with the semiconductor industry for which there are thousands of relevant articles.

A compilation of spectral solar reflectance (and spectral long-wave emittance) data for typical building materials would be quite useful. At present it is necessary to search the literature for the properties of individual materials or to make measurements to obtain this information.

Another desirable item would be quantitative information as to how surface roughness enhances the optical absorptance of materials. For a specific surface shape, one could perform Monte Carlo calculations of the increase in absorptance, but what would be more immediately useful is a simple approximate rule for estimating this effect.

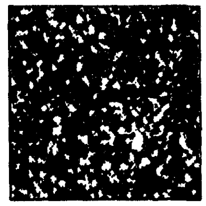
Finally, in summary, to achieve high solar reflectance, one should use high refractive index pigment particles with diameters of 200-300 nm, in a medium with low refractive index. Other possible pigment choices include coated mica flakes and metal flakes. The use of metal flakes, as in the aluminum coatings, must be done carefully to ensure reasonably high infrared emittance. Reflective surfaces should be macroscopically smooth, to avoid the roughness problem. In some cases, hydrogen atoms in the reflective material may lead to objectionable absorption in the near infrared, which should be minimized. For surfaces with a specified color, the solar reflectance can still be maximized subject to this constraint. Even a black color can have a solar reflectance as high as 50%.

# Technical Issues for the Development of Cool Materials

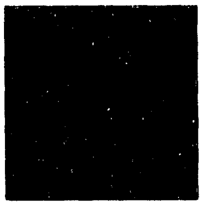
Paul Berdahl (510) 486-5278 and Sarah Bretz

1. Black Acrylic Paint
142°F
Midsummer Temp = 190°F

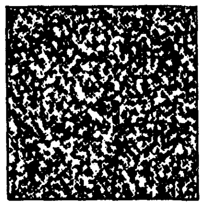
2. Galvanized Steel
138°F



3. Meadow Green Fiberglass/
Asphalt Shingle
129°F

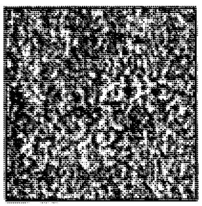


4. Same as (1) with "XIR"
Selective Film
123°F



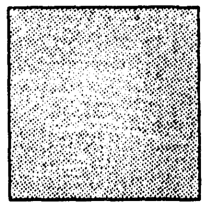
5. "White" Fiberglass/
Asphalt Shingle
118°F

6. Clay Tile
(Terra Cotta)
112°F

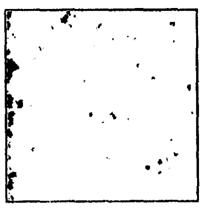


7. Aluminum
Roof Coating
112°F

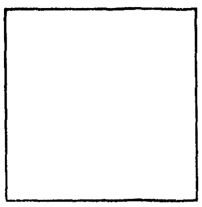
8. $Fe_2O_3 + TiO_2$
Red Acrylic Paint
106°F



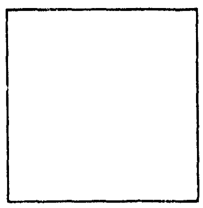
9. $CR_2O_3 + TiO_2$
Light Green Acrylic Paint
104°F



10. Cementinous Coating
on a Mineral Cap Sheet
89°F



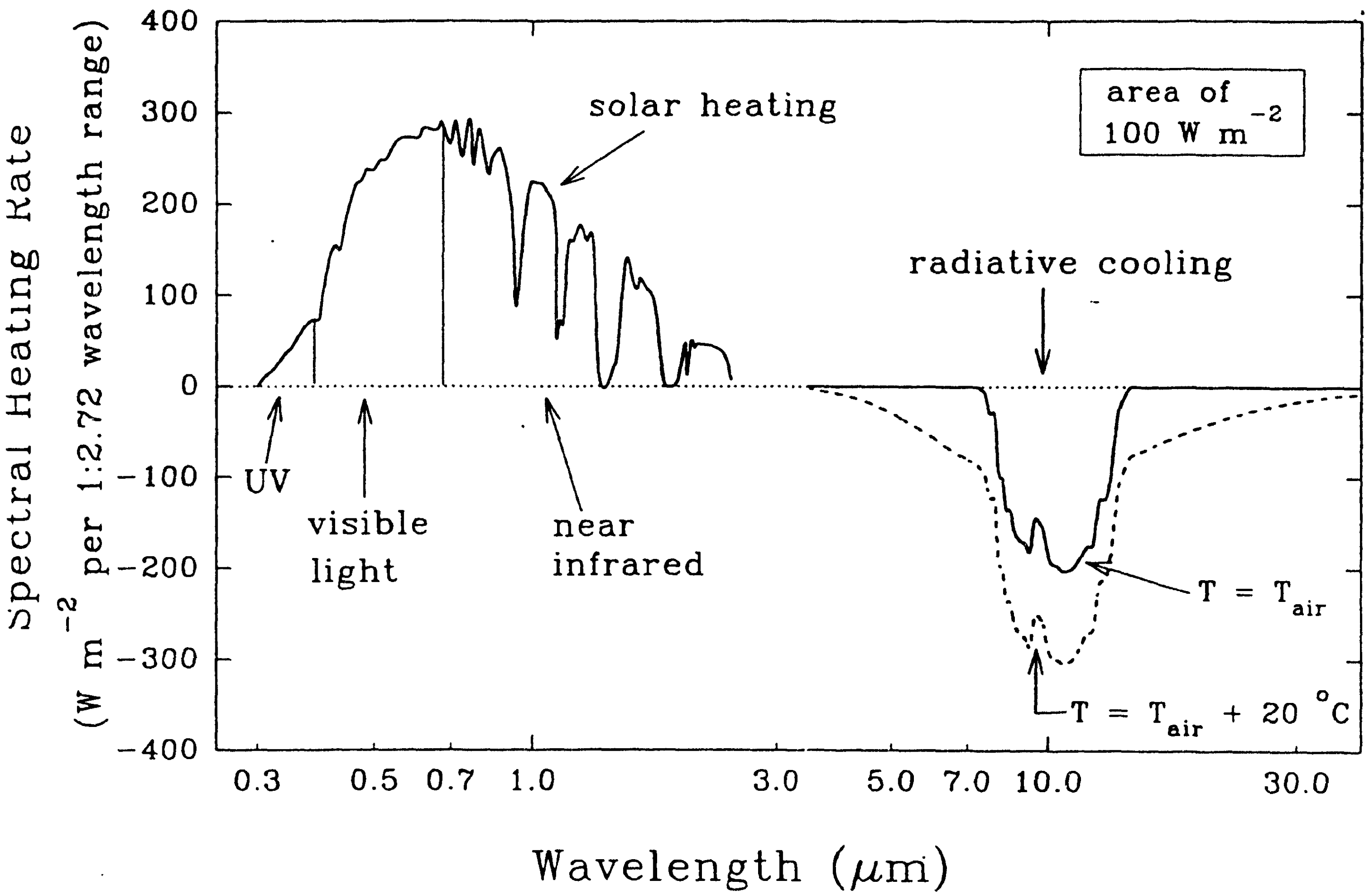
11. $TiO_2$
White Acrylic Paint
74°F



12. Hyper White
Specialty Material
65°F

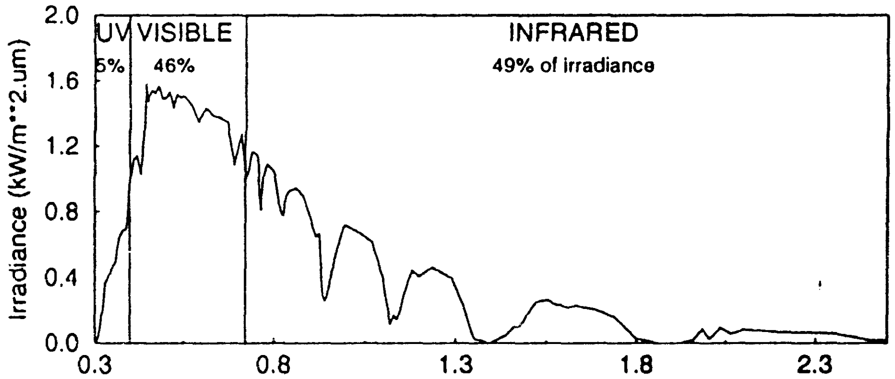
Slide 1

Twelve samples and their surface temperatures at noon, November 1993 Ambient air temperature is 55°F Common roofing materials such as "white" asphalt shingles and galvanized steel are 63°F and 78°F hotter than air temperature, respectively In contrast, Samples 8-12 run cooler, with Sample 12 representing the potential of cool materials

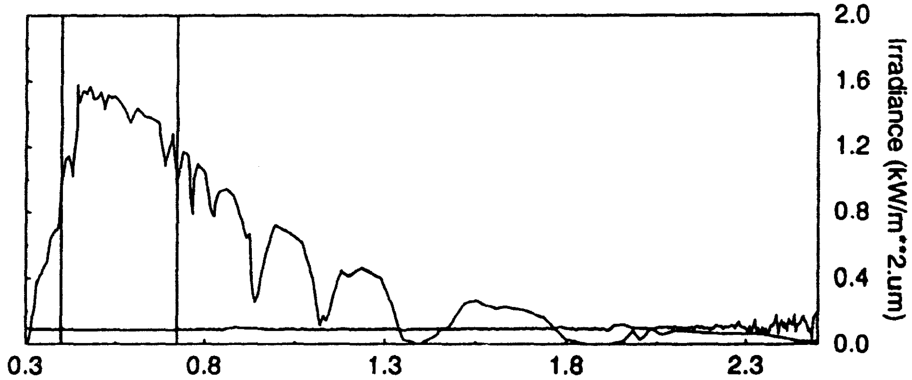


Spectral Heating Rate
(W m^-2 per 1:2.72 wavelength range)
400
300
200
100
0
-100
-200
-300
-400
solar heating
area of 100 W m^-2
radiative cooling
UV
visible light
near infrared
T = T_air
T = T_air + 20 °C
0.3
0.5
0.7
1.0
3.0
5.0
7.0
10.0
30.0
Wavelength (μm)

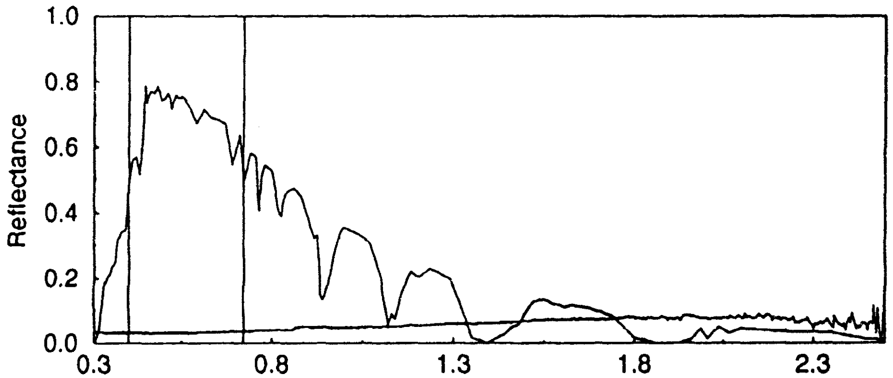

Slide 2.



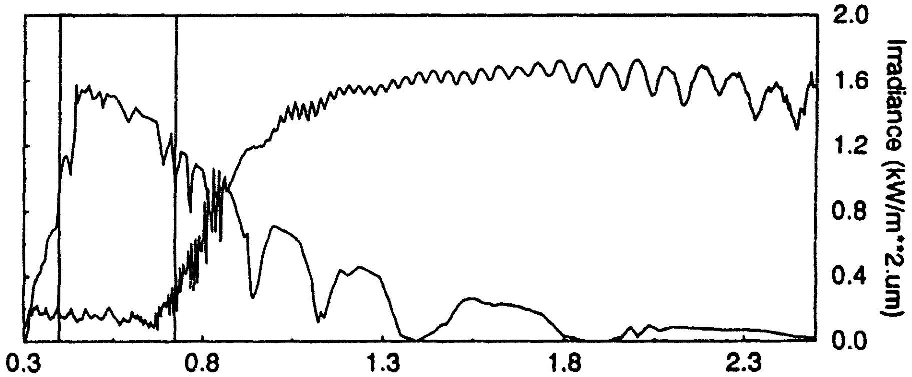
Slide 3. ASTM standard solar irradiance curve (E892)



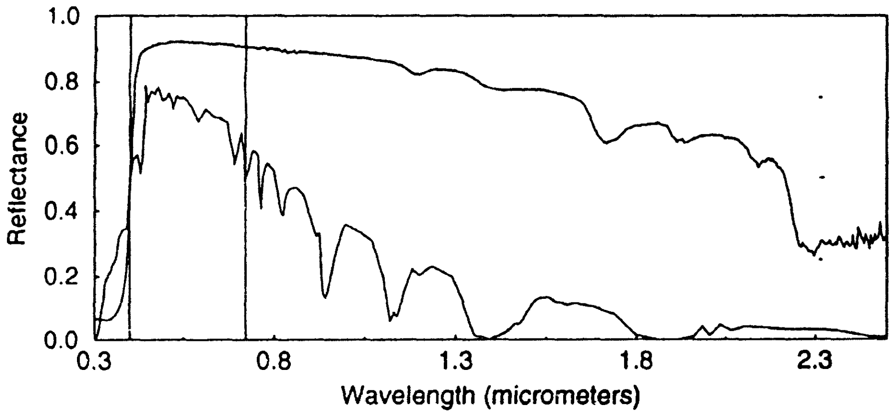
Slide 4. Spectral reflectance of black acrylic on aluminum.



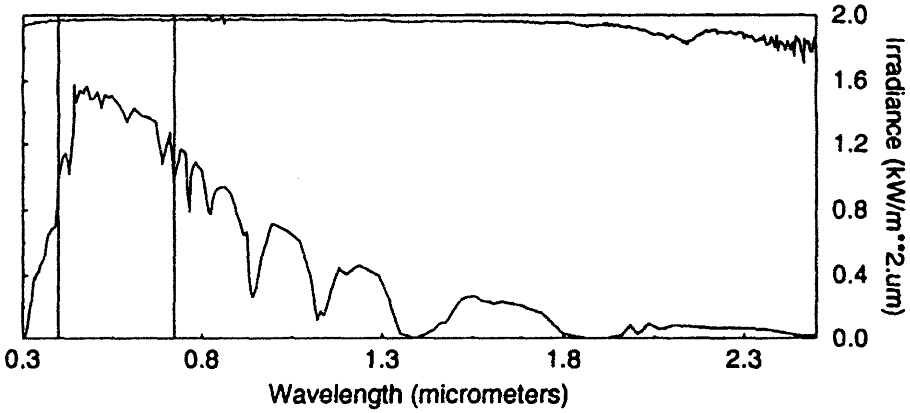
Slide 5. Spectral reflectance of asphalt pavement.



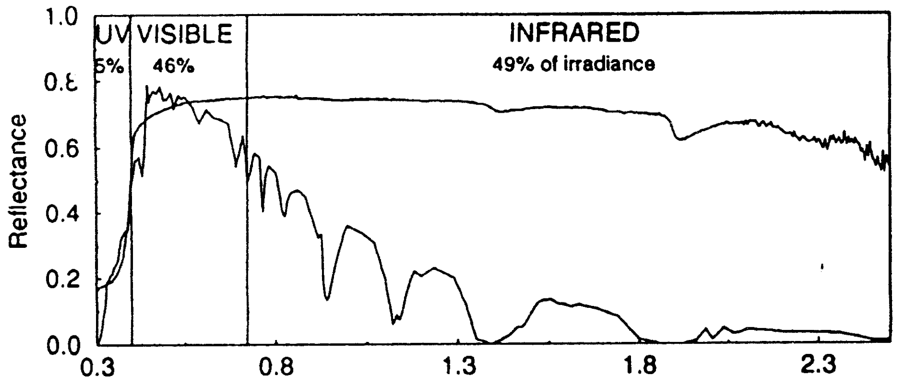
Slide 6. Spectral reflectance of black acrylic and XIR



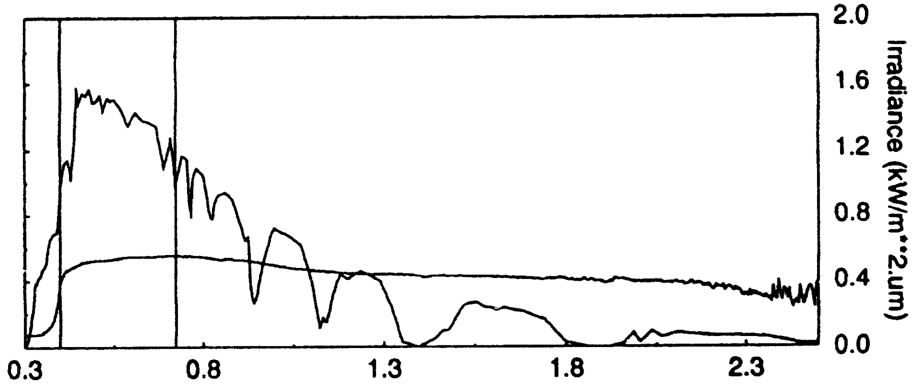
Slide 7. Spectral reflectance of TiO2 acrylic paint.



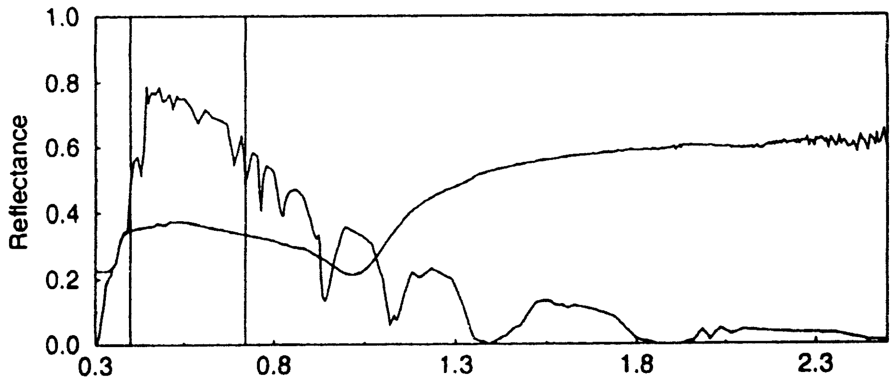
Slide 8. Spectral reflectance of hyper white powder.



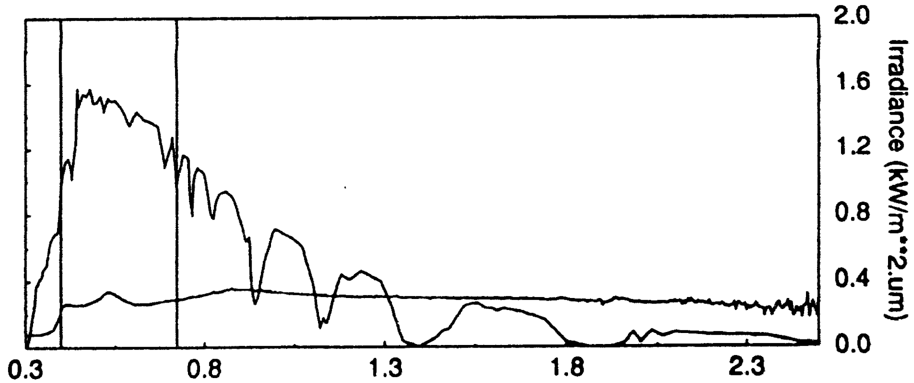

Slide 9. Spectral reflectance of cementitious coated cap sheet.



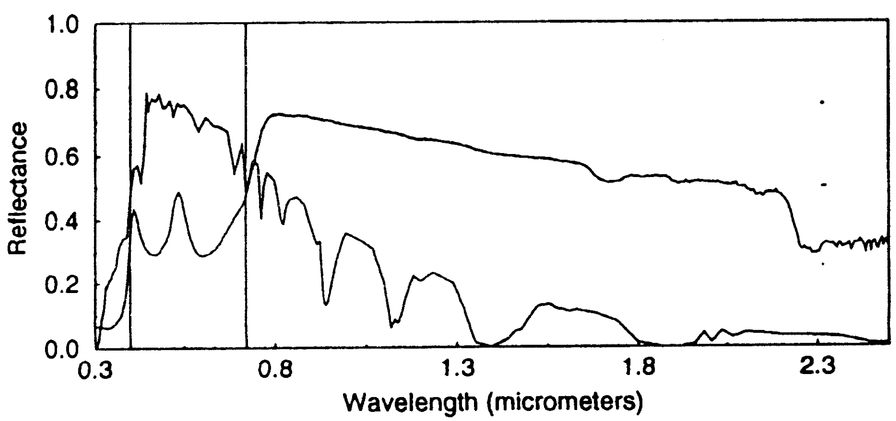

Slide 10. Spectral reflectance of white asphalt shingle.



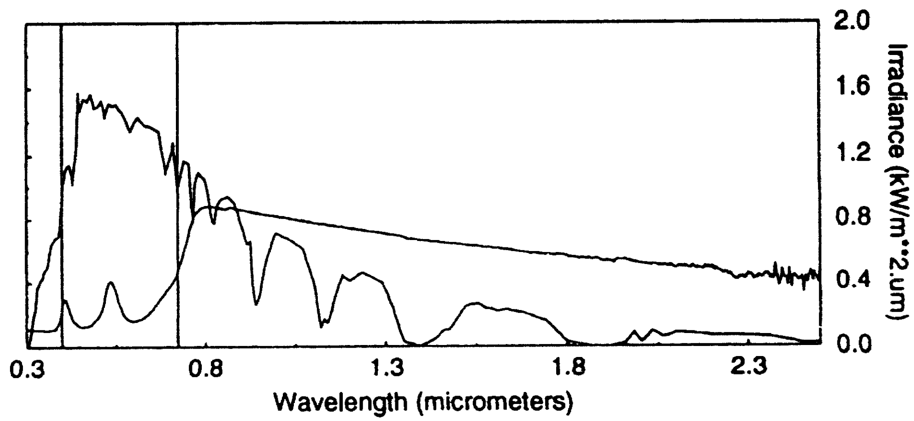

Slide 11. Spectral reflectance of galvanized steel.



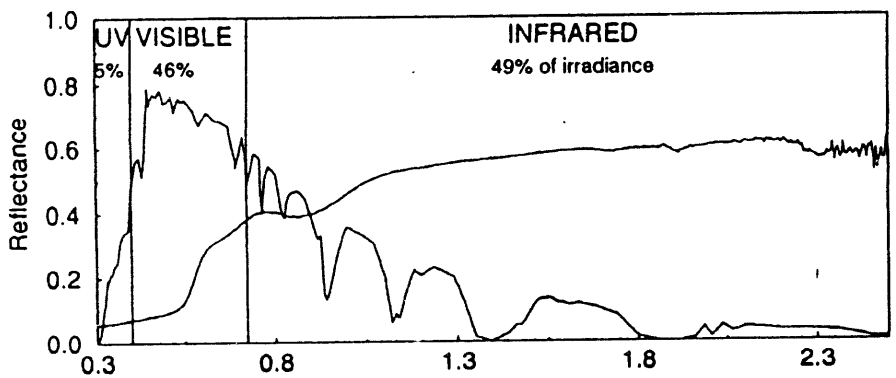

Slide 12. Spectral reflectance of green asphalt shingle.



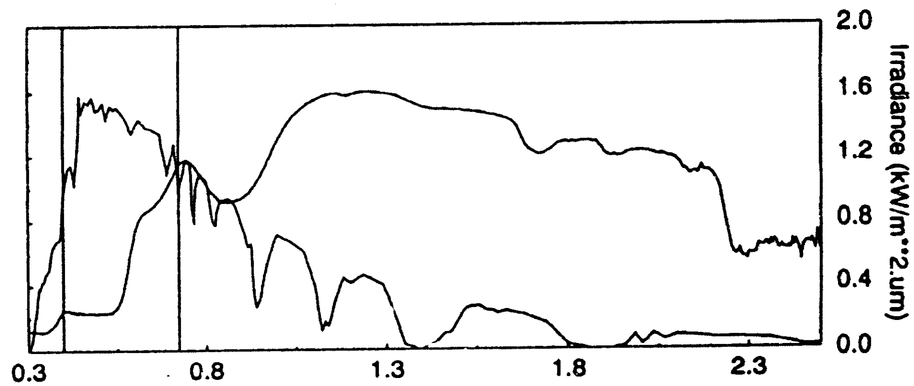

Slide 13. Spectral reflectance of Cr2O3 + TiO2 paint.



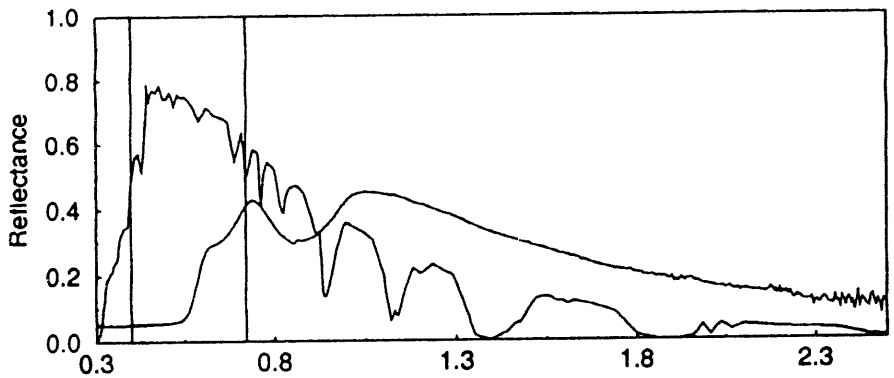

Slide 14. Spectral reflectance of Cr2O3 over black.



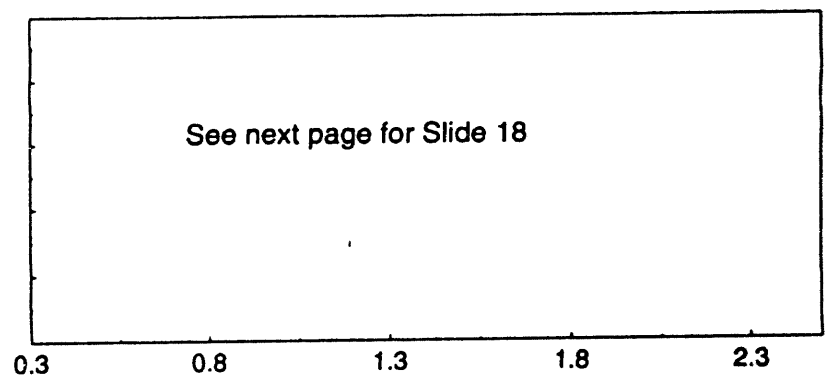

Slide 15. Spectral reflectance of clay tile.



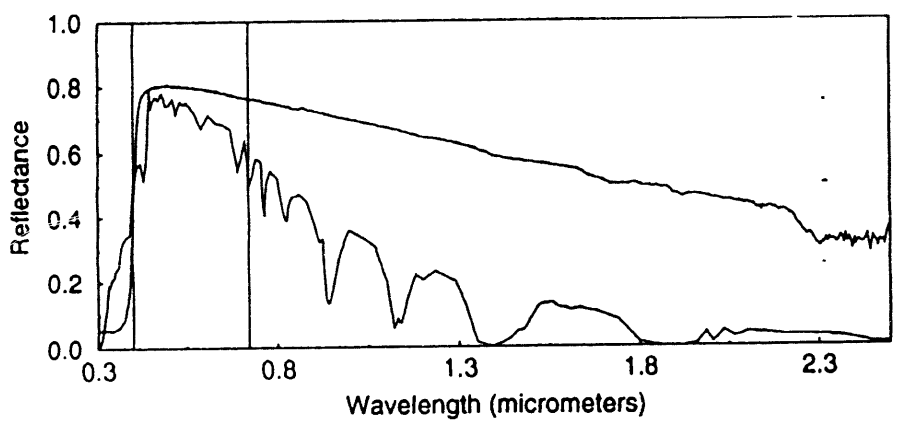

Slide 16. Spectral reflectance of red Fe2O3 paint.



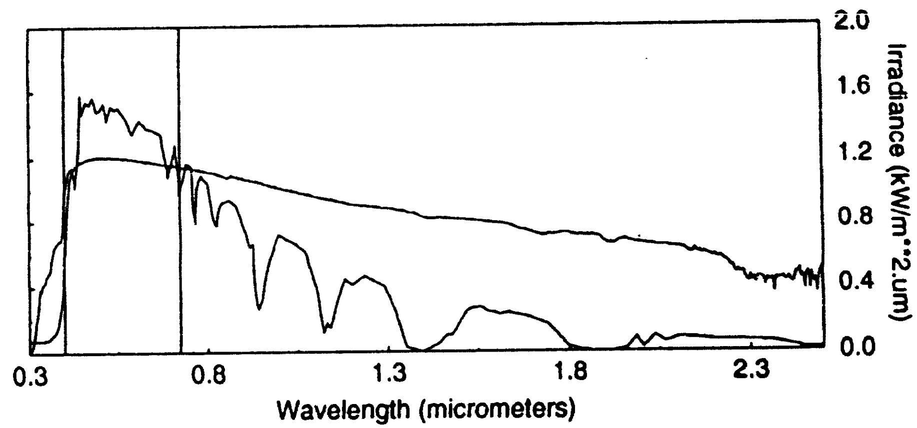

Slide 17. Spectral reflectance of red Fe2O3 over black.



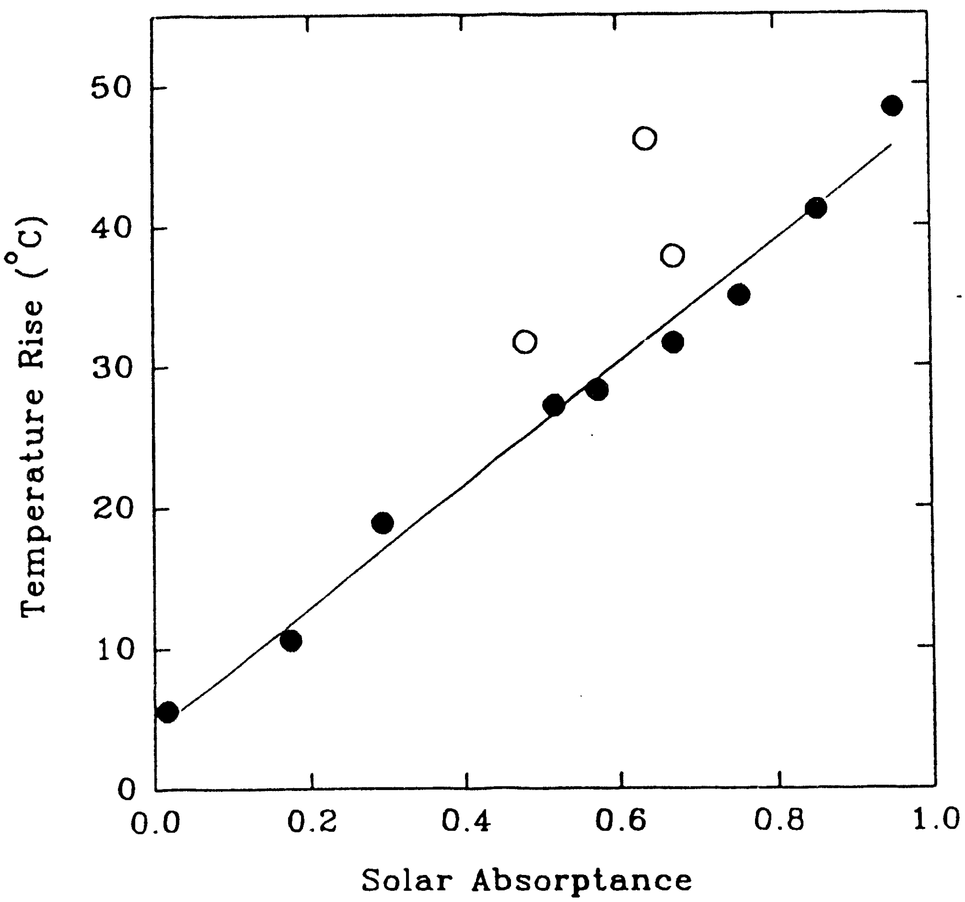

Slide 18. See next page.



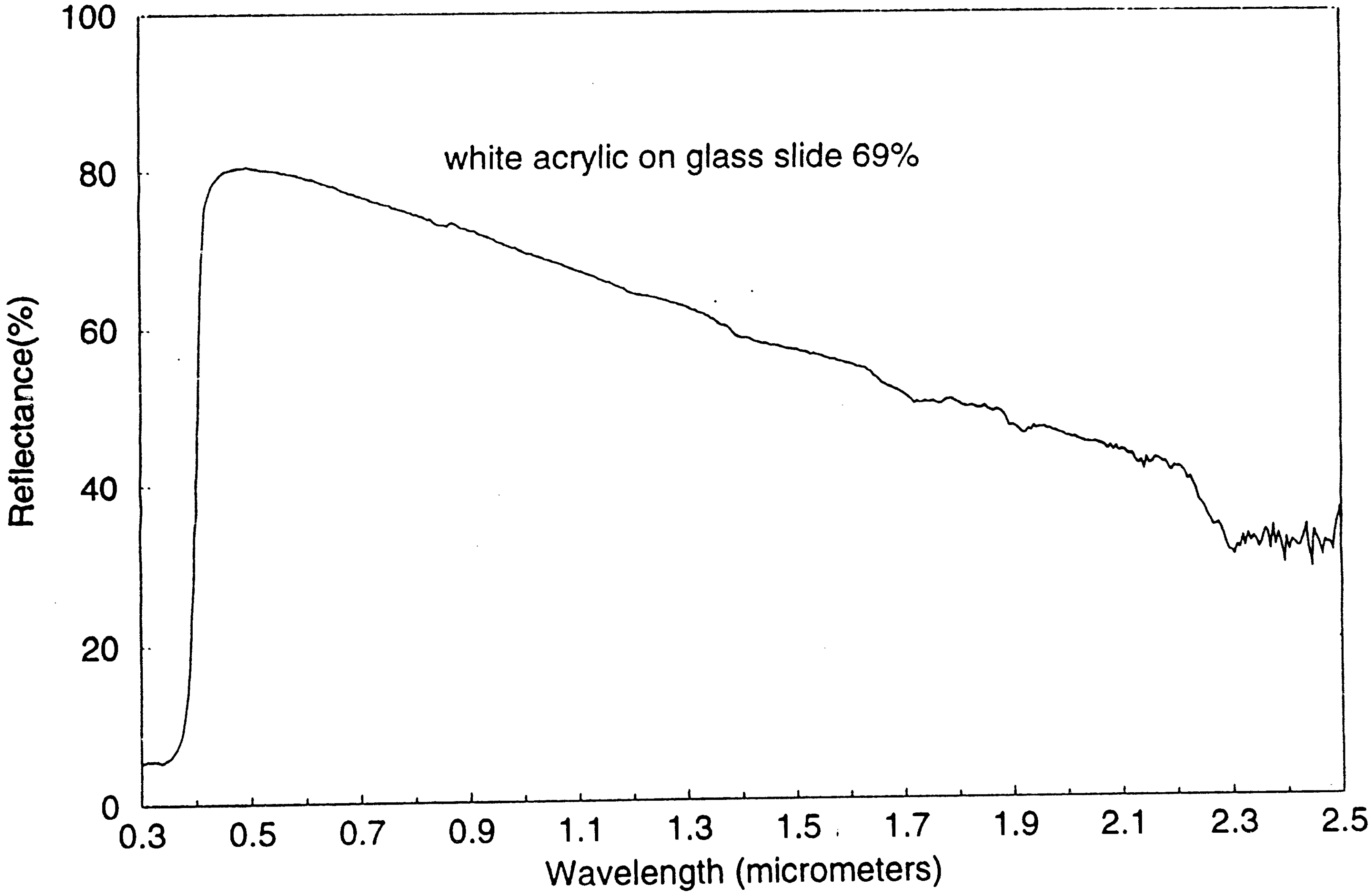

Slide 19. Spectral reflectance of white paint on glass.




Slide 20. Spectral reflectance of white paint on shingle.


0
10
20
30
40
50
0.0
0.2
0.4
0.6
0.8
1.0
Temperature Rise (°C)
Solar Absorptance

Slide 18.


white acrylic on glass slide 69%
Reflectance(%)
100
80
60
40
20
0
0.3
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
2.5
Wavelength (micrometers)

# ATTACHMENT 5

Presentation Summary from Geoffrey Frohnsdorff
National Institute of Standards and Technology

The following is summary of Geoff's presentation on the Coordinated High-Performance Construction Materials Program (CONMAT).

# CONMAT: The CERF-Coordinated High-Performance Construction Materials and Systems Program

Geoffrey Frohnsdorff
Building and Fire Research Laboratory
National Institute of Standards and Technology

The Civil Engineering Research Foundation (CERF), an arm of the American Society of Civil Engineers (ASCE), in conjunction with several other national organizations, is developing an ambitious national program, CONMAT, on high-performance construction materials and systems. The intention is to bring about the investment in research, development, and technology transfer on construction materials and systems that will be needed if the nation's new construction is to be of the optimum quality.

The CONMAT program was announced in April 1993 at a meeting at the Department of Commerce and, simultaneously, in CERF's Executive Report (Report 93-5011.E), "High-Performance Construction Materials and Systems: An Essential Program for America and Its Infrastructure", which was addressed to President Clinton. Information about CONMAT is given in the attached copy of the first issue of the newsletter, CONMAT NEWS.

**It is suggested that the CERF-coordinated CONMAT program would provide a good umbrella for the proposed national cool building materials program.**

CONMAT NEWS

*The Civil Engineering Research Foundation's CONstruction MATerials Newsletter*

**Fall 1993**

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# High-Performance Construction Materials and Systems on the Map!

For over two years, and especially in the last six months, concerted action by a wide range of associations and individuals has focused national attention on research and commercialization of **high-performance construction materials and systems.** We have created a new visibility and immediacy for this effort. Yet our task is only beginning. We must continue our efforts in organization, research and implementation if we are to see major, qualitative breakthroughs in product and process.

Only last April, the Civil Engineering Research Foundation (CERF), supported by the Federal Highway Administration (FHWA), with assistance from the National Institute of Standards and Technology (NIST), held a symposium entitled *Materials for Tomorrow's Infrastructure: An Essential Program for America.* This seminal event, coupled with the publication of *High-Performance Construction Materials and Systems: An Essential Program for America and its Infrastructure,* established the need for such a national program. The National Science Foundation (NSF) similarly addressed infrastructure needs in its January 1993 report *Civil Infrastructure Systems Research: Strategic Issues.* The Clinton Administration, whose goals include revitalizing the nation's infrastructure, commercialization of new technologies, enhancement of the environment, and improvement of the nation's competitive stature, warmly endorsed the concept of the projected 10-year, $2 billion-$4 billion CONstruction MATerials and Systems effort (CONMAT) for rapidly exploiting the potential of high-performance materials.

This program had its origin in CERF's 1991 National Civil Engineering Research Needs Forum. Prior to the symposium, the focus was primarily on initiatives for concrete and steel. Since that time, other materials groups have rapidly emerged, including aluminum, asphalt, coatings, polymers/composites, masonry, roofing materials, smart materials, and timber. The program focus, organizational support structure, and strategic objectives for many of these groups are outlined in this newsletter. While detailed research objectives and implementation strategies are still being formulated, the development of each of these materials groups is a major step toward realization of the major qualitative technical and system breakthroughs that are envisioned as products of this 10-year program.

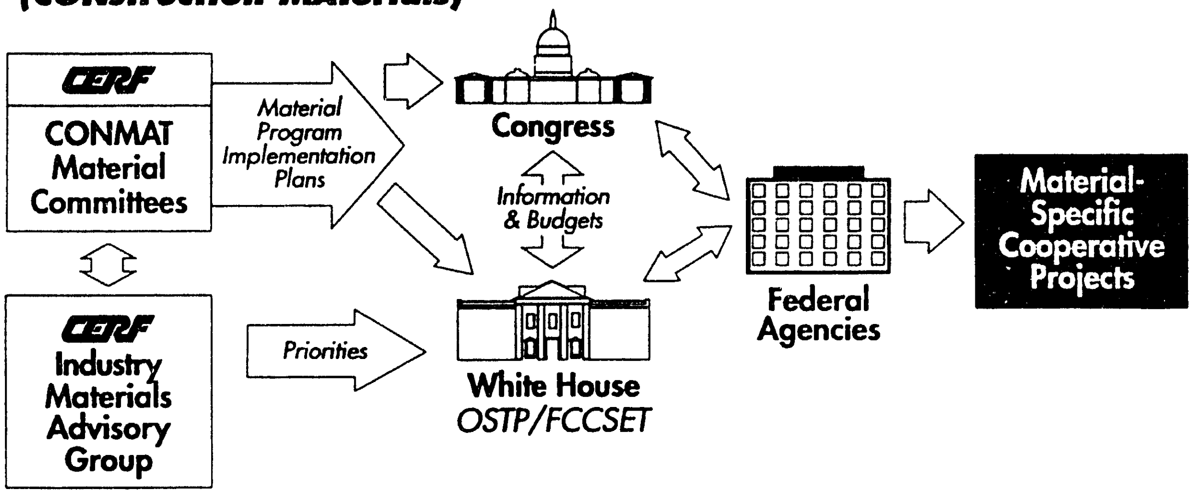
All this planning and organization have reaped impressive rewards! The increased prominence and attention afforded advanced construction materials has resulted in explicit federal recognition for future funding decisions. The Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) Committee on Industry and Technology (CIT) has recently broadened the definition of "manufacturing" under the Advanced Materials Technology (AMT) Initiative to include *buildings and infrastructure.* The addition of this sector is largely the result of work by the White House Office of Science and Technology Policy (OSTP), CERF, NSF, and NIST.

The AMT initiative, one of six FCCSET initiatives in the President's FY94 budget, was created to expedite the development and commercialization of advanced manufacturing technologies. By specifically designating *building and infrastructure,* the federal government is recognizing the importance and the needs of the construction industry on a level never attained before.

The CONMAT process, involving close interaction among CERF, industry materials groups, the White House, the Congress, and many federal agencies, is graphically presented on the following page.

## Contents

## CONMAT Process
### (CONstruction MATerials)




# Aluminum

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | 80% |
| Research Priorities Identified | 80% |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

Widely used for many years in major structural applications in commercial and military aircraft, pressure vessels, and space-vehicle structures, aluminum alloys have not been widely considered for basic infrastructure application such as bridges, primarily because the basic metal price makes the first cost of aluminum structures 50-100 percent higher than that of steel and concrete structures. However, on a life-cycle cost basis, where short erection times and very low maintenance costs are considered, the economic picture is much different.

The basic properties of aluminum that make it particularly attractive for infrastructure applications include: light weight, one-third that of steel or concrete; high strength, as high or higher than conventional steels; superior corrosion resistance, minimizing maintenance concerns; extreme workability, including by the versatile extrusion process; and fabricability, by a choice of joining technologies.

These properties and characteristics of aluminum alloys translate into four major infrastructure advantages:

- High strength efficiency,
- Flexible options in fabricability,
- Quick, low-cost assembly and erection, and
- Low-maintenance costs.

Technology Transfer is needed to translate the technology from successful use of aluminum alloys in significant structural applications, such as aerospace structures, into comparable infrastructure applications, such as bridges. Lastly, innovative practices can build on the early experience with aluminum in infrastructure applications such as bridges, and experience from other structural applications such as aerospace, to apply solutions to the critical needs of infrastructure enhancement.

Following are specific infrastructure development programs for aluminum alloys:

**Aluminum Bridge Program.** Develop, test, and demonstrate optimized designs for aluminum bridge decks to replace steel bridge decks and for new bridges, providing increased load capacity, faster erection times, and lower maintenance.

**Aluminum Earthquake Resistant Structures.** Develop, test, and demonstrate earthquake-resistant structures of aluminum, taking advantage of the low modules of elasticity for improved survivability.

**Precision Forging and Casting Technology Transitions.** Exploit advantages of advanced aluminum casting and forging technology for improved and cost-effective infrastructure applications.

**Aluminum Battery Power for Infrastructure Applications.** Develop a cost-effective, clean-operating electric power source based upon aluminum-air or aluminum-sulphur battery technology, based on new developments at Clark University.

**Educational Materials for Aluminum Design.** Create educational materials, including course materials, computerized expert systems and videos, to illustrate the advantages and opportunities for application of aluminum engineering design of aluminum structures.

# Asphalt

| | |
|---|---|
| Materials Group Formed | Yes* |
| Planning Underway | Yes* |
| Program Plan Completed | No |
| Research Priorities Identified | No |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

*Not formally with HPCMS program, but on parallel track.

A group of Hot Mix Asphalt (HMA) pavements experts has been assembled to discuss research needs for the HMA Industry. The goal of the forum is to identify research needs for the HMA Industry. The group was initiated by Federal Highway Administration (FHWA) and has agency, industry and academia participation.

The organizational meeting was held in May 1993. At this meeting, presentations were given describing current activities of the organizations represented. The next meeting is scheduled for December 1993, with the specific objective of beginning the process of developing research needs statements.

# Acronyms

ACI–American Concrete Institute
AFPA–American Forest & Paper Association
AISI–American Iron and Steel Institute
AMT–The Advanced Materials Technology Initiative
ARMA–The Asphalt Roofing Manufacturers Association
ARPA–Advanced Research Projects Agency
ASCE–American Society of Civil Engineers
ATP–Advanced Technology Program
AWC–American Wood Council
CERF–Civil Engineering Research Foundation
CERL–The U.S. Army's Construction Engineering Research Laboratory
CIT–Committee on Industry and Technology
COMAT–Committee on Materials
CONMAT–Construction Materials and Systems Program
ConREF–ACI's Concrete Research and Educational Foundation
CRC–Concrete Research Council
FCCSET–Federal Coordinating Council on Science, Engineering and Technology
FHWA–Federal Highway Administration
HMA–Hot Mix Asphalt
HPCCC–High-Performance Concrete Coordinating Committee
HPCMS–High-Performance Construction Materials and Systems
MCA–The Metal Construction Association
NAPA–National Asphalt Pavement Association
NCMA–National Concrete Masonry Association
NCMCC–National Construction Materials Coordinating Council
NIST–National Institute of Standards and Technology
NRCA–National Roofing Contractors Association
NSF–National Science Foundation
OSTP–White House Office of Science and Technology Policy
PIMA–The Polyisocyanurate Insulation Manufacturers Association
SPRI–The Single Ply Roofing Institute
SSPC-Steel Structures Painting Council
TRP–Technology Reinvestment Project

# Coatings

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | No |
| Research Priorities Identified | No |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

The coatings group is planning its first meeting on November 2-3, 1993, at NIST headquarters in Gaithersburg, Md. It will be led by the Steel Structures Painting Council, a national technical organization dedicated to improving the technology and practice of protective coatings for industrial structures.

The initial working group will consist of representatives from facility owners, coating manufacturers, raw materials suppliers, coating applicators, equipment suppliers, university researchers, consulting engineers, and specifiers.

Initially, the group will identify current uses of protective coatings for infrastructure and the role of coatings in relation to other means of protecting against corrosion and degradation. Secondly, the group will examine the effectiveness of currently used coatings and prospects for improving current materials and techniques and of introducing radical new technology.

The impact of regulations on the development and use of protective coatings for the infrastructure and life-cycle costs of corrosion protection, including means to establish valid data for materials performance and cost, are the third and fourth items to be examined.

From the preceding discussions, suggestions will be made for developing, evaluating, and implementing new technologies, potential resources, and major players in this activity.

# Composites

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | No |
| Research Priorities Identified | 90% |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

The Civil Engineering Research Foundation (CERF) established a working group to discuss ways to incorporate advanced composites in infrastructure. NIST was asked to help coordinate the working group.

Group members include representatives from Dow Chemical Co., DuPont, Owens-Corning, the Naval Ship Warfare Center, engineering and design consulting firms, national materials associations, the University of Wyoming's Civil Engineering Department, the University of Delaware Composite Manufacturing Science Laboratory, the U.S. Army Corps of Engineers at CERL, the Federal Highway Administration (FHWA), NIST, and others.

The working group is producing a document titled, *High Performance Construction Materials and Systems: An Essential Program for America and Its Infrastructure, Report on Polymer Matrix Composites in the Infrastructure.*

In it, the working group outlines a new "composite philosophy" in which individual materials (including steel, concrete, timber, etc.) are joined in new and unique combinations that offer improved performance compared to each material by itself. The philosophy being articulated is not a specific materials technology, but, rather a process.

To apply this new composites philosophy, it will be important to identify specific applications where composites can bring the greatest value and most performance-additive for development and demonstration in the rebuilding of America.

Potential uses of composites in the infrastructure include structural stay-in-place form work for concrete construction; composite prestressing tendons and chucks for prestressed columns, beams and slabs; super-prestressing of concrete structurals using composites; optimized/tailored/standardized modular bridge decks; composite structural piling and sheet pile for waterfront and inland installations; and magnetic levitation infrastructure.

There are a number of issues that must be addressed in order to overcome barriers to implementing composite materials. Current industry limitations need to be lessened. Technology transfer mechanisms and government-industry collaborations should be implemented to lessen resistance to composite materials. Cost vs. performance issues also need to be examined.

## Concrete

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | Yes |
| Research Priorities Identified | Yes |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

Since the April 29, 1993, Symposium at which the program for High-Performance Construction Materials and Systems (HPCMS) was announced, the American Concrete Institute has developed plans for a High-Performance Concrete Coordinating Committee (HPCCC). This committee will be formed under the auspices of ConREF, ACI's Concrete Research and Educational Foundation, and will be assisted by the ConREF Concrete Research Council (CRC).

HPCCC members will be key decision makers from the concrete industry appointed by ConREF. They will include consulting engineers, materials suppliers and contractors. Under a charge from HPCCC, CRC will separate proposed projects in the national HPC plan into basic and applied research categories, HPCCC will then prioritize projects in the applied category.

Once the projects have been prioritized, CRC will work with the appropriate federal agency to assemble Expert Task Groups for the high priority projects. They will assist in picking the most promising area and help write objectives and scope for projects, subject to review, modification, and approval by HPCCC and the federal agencies involved.

With input from CRC, the HPCCC will consider possible consortiums and funding for technology transfer which might include demonstration projects, seminars, training programs, or similar activities.

The HPCCC will not be chosen and activated until funding for at least some of the HPC programs is reasonably certain. However, it's important to maintain the momentum and enthusiasm for the program's goals. Thus, at the Nov. 2 meeting, members of the concrete working group from the April 29 meeting will concentrate on preparing further input for use by HPCCC. The input will include recommended criteria for prioritizing various phases of the HPC plan and recommended management strategies for implementing the plan. The concrete working group will also explore further means to stimulate industry involvement.

## Masonry

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | 80% |
| Research Priorities Identified | 80% |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

The Council for Masonry Research has appointed a steering committee that has agreed to review the masonry industry's present "Research Needs for Masonry," August 1988, as conducted by the Department of Civil Engineering, Clemson University, and supported by a National Science Foundation grant.

The steering committee is made up of: Richard Klingner, University of Texas; Denis Brosnan, Clemson University; Howard

Droz, Smith, Henchman & Grills; Al Isberner, Isberner Consulting; Ervil Stabb, U.S. Corps of Engineers; Mark Hogan, National Concrete Masonry Association; Gregg Borchelt, Brick Institute of America; and Tony Fiorato, Portland Cement Association.

This activity's sponsor, the Council for Masonry Research, consists of six national organizations, including: Brick Institute of America, Mason Contractors Association of America, National Concrete Masonry Association, National Lime Association, Portland Cement Association, and The Masonry Society.

# Roofing Materials

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | No |
| Program Plan Completed | No |
| Research Priorities Identified | No |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

The roofing materials steering committee will be composed of representatives from five of the leading organizations in the industry: The National Roofing Contractors Association, The Asphalt Roofing Manufacturers Association, The Single Ply Roofing Institute, The Polyisocyanurate Insulation Manufacturers Association, and The Metal Construction Association. Collectively, these groups represent the vast majority of the $16 billion U.S. roofing industry.

The November meeting will be the first effort by this group to consider high-performance construction materials. The group's primary goal will be to determine which aspects of the high-performance program are most appropriate, and to begin a strategic planning process.

Roofing materials include traditional bituminous membranes, as well as newer thermoset and thermoplastic materials, and standing-seam metal and metal panels.

# Smart Materials

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | No |
| Research Priorities Identified | No |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

The smart materials planning group's working consensus is that smart structures and materials technologies have much to offer in the specific areas of health monitoring of existing structures using techniques such as the fiber-optic strain sensors, corrosion sensors, and ferroelectric strain sensors. These could be used to avoid unpredictable failures and to devise appropriate maintenance strategies based upon cause not schedule. This would provide a significant reduction in the inspection burden for the numerous bridges and highways within the U.S. (although the panel sees the main utility of this technology being for bridges that are known to have possible corrosion or fatigue problems).

There was also interest in developing self-stiffening structures that would only draw power during a situation of excessive loading. It was suggested that this would make an excellent pilot project to serve as a test for reduction of wear to bridges not designed for normal heavy loads. The group felt it would be desired to develop a test bed that could be used for a number of advanced projects in "smart" sensing and actuation.

The group hopes to be joined at the November meeting by a number of major companies interested in pursuing this activity, including Lockheed, Grumman, and Dupont. It will also be joined by several small companies such as Strain Monitor Systems, Quantum, as well as university representatives from Vermont University, UCLA, MIT, Catholic University, and others already involved in placing health monitoring systems using fiber-optic or ferroelectric sensors onto civil projects including bridges, dams, and buildings.

The group hopes to draft a comprehensive plan that will provide a test bed that would be available to R&D groups in industry, academic, and national lab environments to pursue actual experiments and gather data to determine the usefulness of a variety of technologies for health monitoring and self-stiffening.

# Steel

| | |
|---|---|
| Materials Group Formed | Yes |
| Planning Underway | Yes |
| Program Plan Completed | Yes |
| Research Priorities Identified | Yes |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

In 1991, CERF's workshop on defining a national research agenda for the civil engineering profession identified high performance steel and concrete as one of five key areas necessary to advance civil engineering technology. At that time, AISI formed a task force of industry, academia, and consultants to develop a research and implementation plan to meet this challenge. Over 60 individuals have been involved, representing key industry trade associations and technical committees.

The steel plan, outlined in CERF Report 938, *High-Performance Construction Materials and Systems: An Essential Program for America and Its Infrastructure*, presents the results of their work: a definition of high performance steel, a vision statement regarding its application to various construction products and systems, and the identification of five key technology areas requiring research and development. From the beginning the effort has focused not only on steel materials but also on other aspects of a steel construction system necessary to achieve high performance.

Since the report's publication in May, the steel group has participated in these activities: reviewed the larger steel community's plan to better define programs and dollars; prioritized technical programs and projects; visited key federal agencies to determine their priorities and interests in the initiative; and discussed implementation strategies.

The High-Performance Steel Steering Team and Plan Section leaders include: Mike Engestrom, Nucor-Yamto Steel Sales Corporation; Alex Wilson, Lukens Steel Company; Roger Wildt, Bethlehem Steel; John Barsom, U.S. Steel Group; James Fisher, Computerized Structural Design; John Fisher, Lehigh University; Nestor Iwankiw, American Institute of Steel Construction; John Gross, NIST; Laurie Grainawi, Steel Tank Institute; Richard Sause, ATLSS; William Wright, Turner-Fairbanks Highway Research Center; and Kathleen Almand, AISI.

## Timber

| | |
|---|---|
| Materials Group Formed | No |
| Planning Underway | No |
| Program Plan Completed | No |
| Research Priorities Identified | No |
| Implementation Plan Completed | No |
| Identification of FY96 Funding Needs | ? |
| ATP Candidate | ? |
| TRP Candidate | ? |

## New Funding Opportunities

Industry should be aware that there are emerging opportunities for significant research and commercialization support! One exciting possibility is the Advanced Technology Program (ATP) at NIST. Begun in 1990, this program targets *high-risk technologies* "with substantial potential for enhancing U.S. economic growth." Awards to individual companies are limited to $2 million over 3 years and are limited to direct R&D costs. Awards for joint ventures may be up to 5 years, with the joint venture partners providing more than 50 percent of the resources for the effort. The Congress has recently approved increased funding of ATP from $69 million to $200 million. NIST expects to have $750 million in ATP by 1997.

In its initial years of operation, ATP used general competitions in all technology areas as the single investment strategy. The program now is planning to focus on specific *program areas* in order to have the greatest possible impact on technology and the economy; NIST is actively soliciting recommendations for program areas. The programs areas will be selected according to four criteria: "potential for U.S. benefit, good technical ideas, strong industry commitment, and the opportunity for ATP funds to make a significant difference." As mentioned above, high-risk technologies are specifically targeted.

CERF, along with other industry groups, intends to submit two program areas for consideration: one for *Advanced Construction Technologies* based on the 1991 Forum (*Setting a National Research Agenda for the Civil Engineering Profession*) Thrust Areas/Research priorities, with the second focusing on our CONMAT program, *High-Performance Construction Materials and Systems.*

Our industry should also take advantage of the greater role that the Department of Transportation (DOT) may be playing in the defense conversion projects sponsored by the Technology Reinvestment Project (TRP) under the Advanced Research Projects Agency (ARPA). Secretary Pena has indicated a desire to join with other agencies (NIST, Defense, Energy, NASA, NSF among them) in evaluating proposals that address the department's concerns. Among the key department priorities are *infrastructure maintenance, new vehicles, and environmental monitoring*. One project that will be supported by TRP is the nation's first vehicular composite bridge, to be built in San Diego, Calif.

Clearly our industry must seize the moment and take advantage of these opportunities. It would be tragic if we did not take full advantage! It is critical to make progress in planning; **each materials group must develop detailed implementation plans that realistically define *research priorities* and consider all *implementation issues*.** In order to make accurate and effective budgetary and funding requests, the materials groups should delineate specific funding needs, focusing on the FY 96, 97, and 98 budget cycles, as well as projecting for longer-term projects. Explicit timelines must be developed, so that, as an industry and as individual materials groups, we will be able to make effective use of initiatives developed and administered through OSTP, ATP, and TRP. CERF's status as industry representative will proceed with a goal of maximum industry involvement in order to coordinate and articulate our needs effectively. Our efforts to date are impressive initial steps--**let's maintain our momentum!**

# High-Performance Construction Materials Working Committees and Contact List

**CONMAT Program Coordination**

**Civil Engineering Research Foundation**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President

Carl O. Magnell
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Richard A. Belle
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1111 19th Street, N.W.
Suite 700
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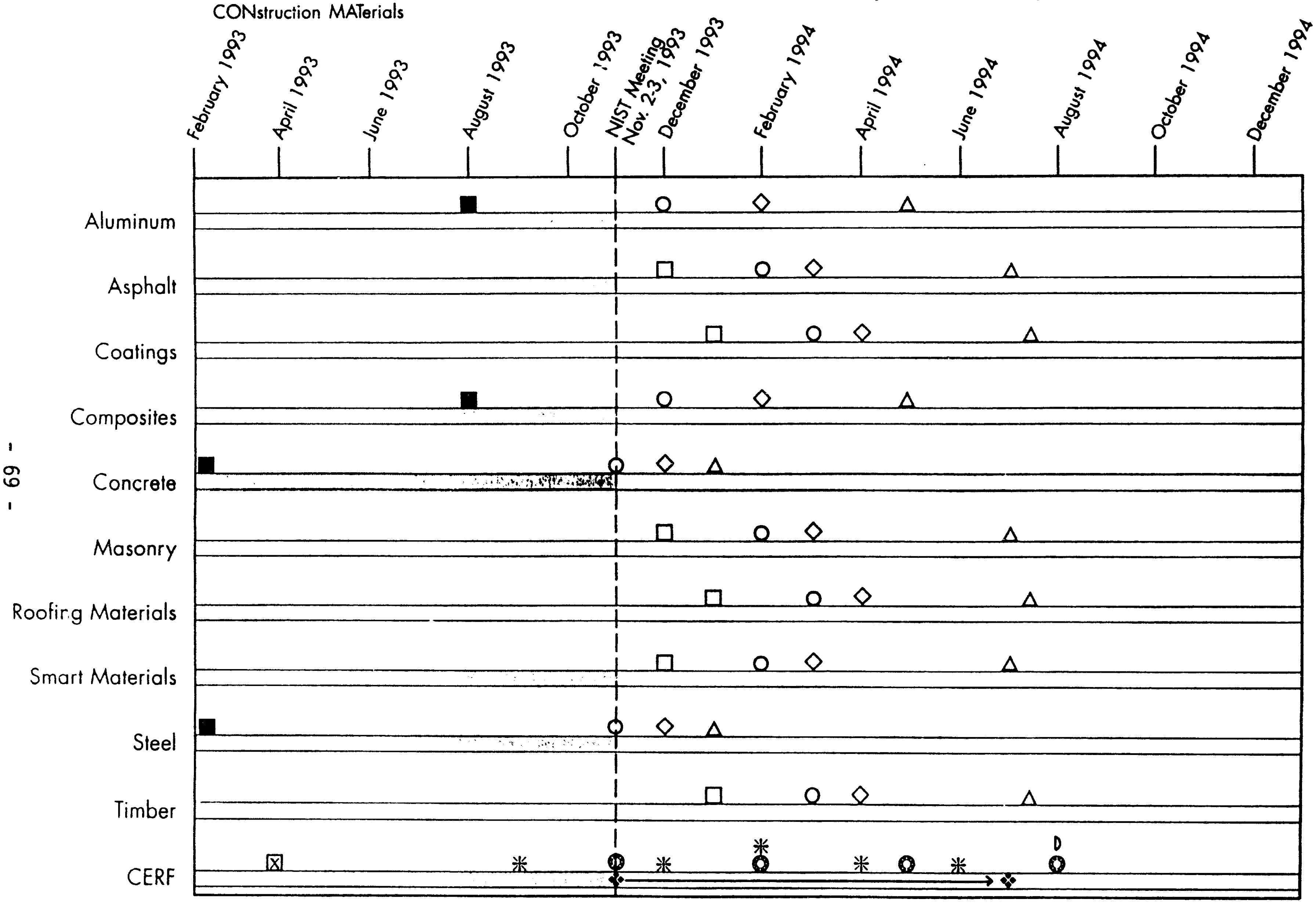
# CONMAT Timeline 1993-1994 (preliminary draft)

CONstruction MATerials




**Legend**

- □ Program Plan
- ○ Research Priorities/Budget White Paper-Draft
- ◇ Research Priorities/Budget White Paper-Final
- △ Materials Group Action Plans
- ☒ CONMAT Publications
- ✪ Newsletter
- ✳ OSTP Meetings as Needed
- ❖ Forming/Assembling Industry Advisory Group
- D Publish National Implementation Plan/Remaining Materials Groups Program Plans

Note: Shaded symbols or shaded horizontal lines signify completed activities.

CERF

## ATTACHMENT 6

Clinton-Gore Climate Action Plan
Option 9: Cool Communities

Action #9

**Expand *Cool Communities* Program in Cities and Federal Facilities**

DESCRIPTION: DOE will mobilize community and corporate resources to strategically plant trees and lighten surfaces on buildings, to reduce air conditioning energy use. Strategic tree planting to shade residential and commercial buildings can reduce energy use and yield cost savings of 10-50%, when combined with lightening building surface colors (especially on roofs) to reduce absorption of sunlight. This initiative expands the existing public/private *Cool Communities* pilot program, founded by EPA and American Forests in 1991, to 250 cities and communities, and to 100 DoD bases and other federal facilities over a ten-year period. DOE and its partners will achieve this expansion nationally through a concerted technical assistance and education effort. *Cool Communities* will organize cooperation among city planners, developers, utilities, community organizations, and Federal facilities managers. Also, the Federal Government is committed to building 20% of new Federal facilities using *Cool Communities* concepts. Utilities will be encouraged to adopt this approach as a demand-side management strategy to enhance the quality of the urban environment, reduce energy demand, and directly sequester carbon.

IMPLEMENTATION: DOE will solicit partnership agreements with interested parties. Currently, American Forests, DOE's Lawrence Berkeley Laboratories (LBL), DOD, and USDA-Forest Service are involved. In the first 6 months of the program, DOE will hold one training seminar and enroll one additional Air Force base and two new Navy and Army bases as Cool Federal Facilities. DOE will enroll an average of 25 cities per year and 10 federal facilities per year over a ten year period, and hold five regional training seminars. In each enrolled city DOE will sign participation agreements with three corporations and one utility, who will serve as sponsors. The Administration is proposing to obligate $2 million in FY 1995 for this action and $12 million through 2000.

MARKET IMPACT: The cost of the urban tree planting component of *Cool Communities* is based on average tree planting costs of $48-137/tree, plus 50-year maintenance costs of $15-183/tree. Tree planting in this action assumes strategic residential tree plantings shading air-conditioned houses and buildings, of which 25% shade low-income houses. Light colored roofs and pavements may add 5-10% to the cost of routine maintenance and new construction. This action, together with the other Home Improvements initiatives (see table), stimulates about $11.7 billion in private sector investment for the period 1994-2000 (undiscounted 1991 dollars). The Home Improvements investment yields energy savings worth about $5.4 billion through 2000, and continues to pay off over the next decade, for an additional savings worth close to $21.6 billion over the period 2001-2010 (undiscounted 1991 dollars).

EMISSIONS REDUCTION: The emissions impact due to energy savings from this action was analyzed in combination with the other Home Improvements initiatives. Together, these actions reduce greenhouse gas emissions from projected 2000 levels by 4.4 MMT of carbon equivalent. Trees planted for *Cool Communities* also sequester carbon by absorbing carbon dioxide from the atmosphere during growth and photosynthesis, so the program increases carbon uptake by 0.5 MMT of carbon equivalent by 2000.

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